Greening of Industry Networks Studies

Diego A. Vazquez-Brust
Joseph Sarkis *Editors*

Green Growth: Managing the Transition to a Sustainable Economy

Learning By Doing in East Asia and Europe

Springer

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to a Sustainable Economy

Greening of Industry Networks Studies

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Editors

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Acronyms

3D	Tridimensional
APEC	Asia Pacific Economic Cooperation
BAU	Business As Usual
BCA	Building Control Authority, Singapore
BOD	Biological Oxygen Demand
BP	British Petroleum
BRASS	The Economic and Social Sciences Research Council Centre for Business Relationships Accountability and Society at Cardiff University
CAFÉ	Coffee and Farmer Equity
CAPSS	Clean Air Policy Support System
CCS	Carbon capture and storage
CDM	Clean development mechanism (CDM)
CEO	Chief executive office
CERs	Certified emission reductions
CCX	Chicago Climate Exchange
CKD	Completely knocked down kit
CO2	Carbon dioxide
COP	Conference of the Parties
CSP	Corporate social performance
csQCA	Crisp-set qualitative comparative analysis
CSR	Corporate social responsibility
CT	Cleaner technology
DAC	Development assistance committee, OECD
DEA	Data envelopment analysis
DEQP	Thailand's Department of Environmental Quality Promotion
DO	Dissolved oxygen)
ECX	The European Climate Exchange
EEX	European Energy Exchange

EFF^2	Symbiotic compatibility of green and operational effectiveness and efficiency
EIP	Eco-Industrial Park
EMS	Environment management systems
EPA	Environmental Protection Agency, USA
EPP	US Environmentally Preferable Purchasing
ERDF	European Regional Development Fund
ESCB	European System of Central Banks
ESR	Environmental social responsibility
ESRC	The Economic and Social Sciences Research Council, UK
ESS	European statistical system
ETTV	Envelope thermal transfer value
EU	European Union
EUA	European Union Allowance
EU-ETS	EU Emission Trading System
FDI	Foreign direct investment
FSCC	Forest Stewardship Council Certification
GDP	Gross domestic product
GDPI	Green Dynamic Policy Index
GGI	Green Growth Index
GHC	Greenhouse gases
GI	Green innovation
GIN	Greening of Industry Network
GIS	Geographic Information System
GM	General Motors
GM	Genetically modified
GMS	Singapore BCA Green Mark Scheme
GR	Green restructuring
GRI	Global Reporting Initiative
GTI	Green technological innovations
GV	Green value chain
GVW	Gross vehicle weight
GWI	Green Welfare Index
HDB	Singapore's Housing Development Board
HSE	Singapore Health Safety and Environment
HMM	Hyundai Merchant Marine
IDB	Inter-American Development Bank
IEA	International Energy Agency
IES	Innovative energy systems
IHD	Human Development Index
ILO	International Labor Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IR	Increase return

KAU	Korean allowance unit
KIETEP	Korea Institute of Energy Technology Evaluation and Planning
KSGI	Korea Smart Grid Initiative
L&G	Lean and Green
LA	Latin America
LCA	Life cycle assessments
LCGG	Low-carbon, green growth strategies, Korea
LED	Light emitting diodes
LTD	Long-term debt
MCED	5th Ministerial Conference on Environment and Development in Asia and the Pacific
MD	Managing Director
MENA	Middle East and North Africa
MNCs	Multinational corporations
MNEs	Multinational enterprises
MOE	Japan's Ministry of Environment
MONRE	Thailand's Ministry of Natural Resources and Environment
MRV	Monitoring, reporting, and verification
MSs	European Union Member State
NAPs	European Union National Allocation Plans
NCCS	Singapore National Climate Change Strategy
NGO	Non-governmental organization
NIC	Newly industrialized country
NIES	Japan's National Institute for Environmental Studies
NIES	Newly industrialized economies
NOx	Nitrogen oxides
NRF	National Research Foundation of Korea
NYME	New York Mercantile Exchange
OAS	Organization of American States
OECD	Organization for Economic Co-operation and Development
OTC	Over-the-counter markets
OTOP	One Tambon One Product
PAHO	Pan American Health Organization
PCA	Principal component analysis
PCGG	Presidential Committee on Green Growth
PCTC	Pure Car and Truck Carriers
PL	Poverty line
PPEs	Personal protective equipment
PRC	Popular Republic of China
PSC	Ammonium phosphate, sulfuric acid, and cement (joint production technology)
QCA	Qualitative comparative analysis
R&D	Research and development
RBV	Resource-based view

REACH	Registration, Evaluation and Authorisation of Chemicals
SCP	Sustainable consumption and production
SFA	Stochastic frontier analysis
SKD	Semi-knocked down kits
SK-ETS	South Korean Emission Trading mechanism (hereafter
SLA	Sustainable livelihoods approach
SME (*PyME*)	Small and medium enterprises
SO2	Sulfure dioxide
SOEs	State owned enterprises
SOx	Sulphur oxides
SUV	Sport utility vehicle
TNCs	Transnational corporations
TSP	Total suspended particulate matter
UK	United Kingdom
UN (*ONU*)	United Nations
UN	United Nations
UNCPSD	United Nations Commission on the Private Sector and Development
UNCTAD	United Nations Conference on Trade and Development
UNCTMD	United Nations Transnational Corporations and Management Division
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Climate Change Convention
UNFPA	United Nations Population Fund
URA	Urban Redevelopment Authority Singapore
US SIC	United States Standard Industrial Classification System
USA	United States of America
US	United States
VERs	Verified emission reductions, aka voluntary emission reductions
VIF	Variance inflation factors
VOC	Volatile organic compounds
WB	World Bank
WBSD	World Business Council for Sustainable Development
WEEE	Waste electrical and electronic
WHO	World Health Organization
WTO	World Trade Organization
ZAZ	Zaporizhia Automobile Building Plant

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Chapter 1
Green Growth: Managing the Transition to Sustainable Economies

Diego A. Vazquez-Brust and Joseph Sarkis

Abstract This chapter argues that game-changing green-growth must be rooted on economic approaches allowing for the inherent complexity of human-environment relationships, implemented through multi-stakeholders and multi-scale governance arrangements and fuelled by policies and managerial techniques promoting synergies – rather than just decoupling – between environment and growth. The evolution of conceptualizations between growth and environment is first discussed in this chapter. The debate evolves from zero-growth versus uncontrolled growth, to sustainability and parallel discourses emphasizing such principles as ecological modernization and the win-win paradigm. The chapter then describes the emerging discourse of Green Growth and positions this discourse in the context of its predecessors. Transition challenges (e.g. how can we define and measure green growth) and an overview of diverse methods to meet environmental challenges, such as cradle-to-cradle will also be summarized. A framework conceptualizing the main dimensions of Green Growth and mapping the chapters to this framework is then introduced.

Keywords Green growth • Zero-growth • Multi-stakeholders governance • Green markets • Environmental goods and services

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1.1 Introduction

To change the current unsustainable trajectory of the global ecosystem and to remedy lingering stagnation from the financial crisis, key actors are proposing revolutionary economic reforms (Lane 2010). To a large extent political leaders are coming to terms with the concept that such a new economy ought to be based on Green Growth (Hamdouch and Depret 2010). Green Growth goes beyond growth balanced with environmental protection; Green Growth is quality-oriented, low-carbon, energy efficient growth with a focus on creating value through clean technology, natural infrastructure and innovation in markets for environmental goods and services. Green-Growth means making investment in the environment a driver for economic growth. Green Growth strategies should aim to break the vicious cycle between environmental deterioration and unsustainable economic growth-poverty and replace it with a virtuous cycle of quality growth, environmental enhancement and social inclusiveness (i.e., climate action, energy security, sustainable housing) (Shin 2009).

We grapple here with the task of how policy can manage the transition from a growth oriented market capitalism model to a model decoupling economic growth from environmental deterioration. The central focus of this book is the complex relationship between policy, environmental deterioration and economic growth. In particular the design of policy not only decoupling environmental protection and economic growth but also creating positive synergies between them to achieve environmentally sustainable, or 'green' growth. Such a 'de-coupling' and subsequent 're-coupling' is a fundamental paradigm shift. It changes the understanding of relations between environment and growth from negative – growth creates environmental deterioration – to a virtuous cycle where investment in environmental protection and technologies fuels growth. Green Growth also implies a conceptual shift in the design of game-changing environmental policy; substituting 'quality Green Growth economy' for 'zero-growth economy'.

Game-changing Green Growth must be rooted in economic approaches allowing for the inherent complexity of human-environment relationships (Luke 2008). Involvement of multi-stakeholders and multi-scale governance arrangements (Smith 2007; Sarkis et al. 2010) with policies and managerial techniques promoting synergies – rather than just decoupling – between environment and growth need to all be considered in this dialogue (Vazquez-Brust et al. 2009).

The evolution of conceptualizations between growth and environment is first discussed in this chapter. The debate evolves from zero-growth versus uncontrolled growth, to sustainability and parallel discourses emphasizing such principles as ecological modernization and the win-win paradigm. The chapter then describes the emerging discourse of Green Growth and positions this discourse in the context of its predecessors. Transition challenges (e.g. how can we define and measure green growth) and an overview of diverse methods to meet environmental challenges, such as cradle-to-cradle are also summarized. A framework conceptualizing the main dimensions of Green Growth and mapping the chapters to this framework is then introduced. We leave a review of the chapters to the end of the book in a 'Conclusions' Chap. 16, which includes summaries, insights and linkages amongst the chapters.

1.2 Economic Growth and the Environment: From Zero-Growth to Green Growth

The Zero-growth economy was the goal of the 'Survivalist' discourse, represented by the Club of Rome. The Club of Rome was an international organization composed of industrialists, politicians and academics. Its best-selling 1972 report 'The Limits to Growth', used computer generated projections to show that the pattern of population, economic growth and exhaustion of resources, would cause humanity's extinction in less than a century. The report argued that the spread of global market forces at the fuelling unrestrained growth and consumption, would lead to natural resources scarcity and contamination; eventually limiting the capacity of ecosystems to support agricultural and industrial activity. It predicted that, unless something was done to facilitate zeroing of growth in the global economic system, the survival of humankind would be tested within the next century by a catastrophic global environmental and social crisis, leading to famine and wars over access to scarce resources.

Zero-growth became a flagship narrative of environmental activists but fundamentally hindered the formation of a meaningful common agenda with scientists, policy-makers and industry stakeholders (Dryzek 1997). The latter rejected 'zero growth' and supported an alternative paradigm to address environmental problems. This paradigm, termed "Environmental Problem Solving" (EPS) by Dryzek (1997), acknowledged the existence of environmental problems and trade-offs between environmental deterioration and economic growth. However, it denied the existence of a general crisis[1] and the need to reduce growth to forestall a looming 'hypothetical' environmental catastrophe. EPS supports conventional staged models of development purporting an inverted-U-shaped relation between growth and environmental degradation. An increase in environmental deterioration is an inevitable price to pay in initial states of development, but there is a turning point after which any further increases in economic growth is accompanied by increases in industrial efficiency and environmental awareness, eventually leading to reduced environmental degradation and a convergence with developed economies (Kuznet 1966; Berkhout et al. 2010). According to this view, environmental issues are a 'cost' to be paid and a 'problem' to be 'fixed'. Human efforts to curb pollution should be subordinated to economic priorities and organized by the expert intervention of the state. The use of 'end-of-pipe' technologies is promoted by 'tweaking' market structures with 'command and control' regulation and economic instruments.

The conceptual stalemate between 'Survivalist' and 'Problem Solvers' seemingly ended in 1987, when the path-breaking idea that growth is not only compatible

[1] The Limits to Growth was the subject of heated debates. Its detractors argued that computed models were manipulated selecting the least favourable set of assumptions about economic 'feedback mechanisms' by which increases in price will always result in a decrease in consumption, more efficient technologies and more efficient use of stocks.

with environmental protection but also needed to protect the environment was advocated as a core strategy for sustainable development in 'Our Common Future' – also known as 'Brundtland report' (Dryzek 1997). Ecological modernization[2] also argues that social and technological innovation is promoted as a pathway to make economic growth compatible with environmental sustainability – in particular through greener consumption and lifestyles, eco-efficiency and dematerialization.

The concept of sustainable development defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987:43) captured the imagination of policy-makers and industry alike. The discourse emphasizes inter and intra-generational justice and the need to move from top-down government-led regulation to de-centred regulation (voluntary agreements, industry standards, community rules). In this situation agency devolves to business and communities (the end demand and supply of goods and pollution). Sustainability sees economic growth made compatible with environmental protection through an alliance by companies, the State, and civil society, for the exploration of technological, economic and institutional alternatives aimed at reducing poverty, social injustice and inequality, without damaging the environment (Murphy 1994).

However, the Brundtland report is not specific in terms of how these ideas can be embedded in the economic system and how policy should address the needs of future generations. General support of its principles did not equate to consensus over its meaning and implications in practice (Williams and Millington 2004; Seyfang 2001).[3] During the 1990s, a considerable amount of effort attempted translating sustainability ideas into policy; enunciating how a sustainable economy based on green capitalism would actually work. A new branch of economics – ecological economics – was developed to account for the inherent complexity of intertwined biological, social and economic systems (Daly 1990; Costanza 1991; Jansson et al. 1994). Nevertheless, most of mainstream environmental economic policy ignored the ideas of ecological economics. These ideas were – and still are – influenced by what Jacobs (1991) calls the 'orthodox' approach to environmental economics, which uses neoclassical theory to frame the analysis of environmental problems.

In neoclassical environmental economics, the environment is reduced to a set of commodities (environmental good and services) whose demand and supply is governed by market forces. Because environmental commodities (clean air, drinkable water) are free, their demand is not curbed by costs and they are overused, thus

[2] Ecological Modernization comes from social scientist Joseph Huber's (1982) ideas, which see environmental degradation as a structural problem that does not require a radical change in the political-economic system, but a gradual reorganization of the capitalist economic structure to include environmental criteria.

[3] For instance 'weak sustainability" sees the inefficient use of resources as the crucial problem, thus focusing on the use of innovative technologies to improve resource supply and reduce waste (techno-fix). Strong sustainability sees bloated consumption patterns that go beyond earth's carrying capacity as the crucial problem, thus emphazising behaviour change and decrease of human demand (Williams and Millington 2004).

causing environmental deterioration (Jacobs 1991). The challenge of translating sustainability into practice is thus reduced to the design of methodologies to assign present and future prices or monetary values to environmental goods and services. In turn, the ‘business case’ for the incorporation of these concepts in managerial practices has come forward through the so-called ‘win-win’ proposition of being able to win in both economic and environmental terms (Sarkis and Cordeiro 2008). With the support of supranational organizations – World Bank (WB), World Trade Organization (WTO), United Nations (UN) – researchers and policy makers endeavoured to strategise how the potential of markets to encourage environmental protection would be harnessed through a combination of policy instruments including voluntary agreements, environmental taxes, subsidies, regulation and government expenditure. Sustainability and green policies became part of the dominant discourse in policy and management.

1.3 Environment and Sustainability: A Management Approach

The incorporation of ‘sustainability’ into managerial practice was supported through corporate-level ecological modernization (eco-modernization) discourse (Dryzek 1997; Prasad and Elmes 2005). This discourse acknowledges the need for more integration of environmental issues within corporate management strategy (Welford 1995). The key points of this discourse, disseminated by the World Business Council for Sustainable Development (WBCSD) are that there is economic benefits for businesses going sustainable, and that the only practical solutions for environmental problems are those balancing the ‘triple bottom line’ (Elkington and Fennel 1998) of economic, environmental and social interests.

Jänicke (2008) highlighted the importance of government intervention to channel the necessary changes in order to “green” the market economy, and stressed that, if such intervention is adequately coordinated, it is not opposed to the interests of companies. In turn, neo-institutional theory sees environmental management as the reproduction of organizational behaviours in response to political influences such as State pressure or standard collective responses to the uncertainty associated with environmental issues. Companies may respond passively to environmental laws or they can identify competitive advantages in these situations (Porter 1991; Wustenhagen et al. 2008).

In practice, Eco-modernization encompasses a continuum of strategies ranging from ‘weak’ to ‘strong’ versions according to its likely efficacy in terms of promoting sustainability (Dryzek 1997; Christoff 2000). “Weak” eco-modernization has a technical-economic focus on improving the environmental efficiency of production through ongoing innovation and environmental management, aiming at maximizing profit while minimizing environmental costs (Springett 2003). Eco-efficiency encourages technological innovation for the development of more efficient industrial processes, in terms of reducing emissions and resources through a product’s life cycle, combined with the application of economic mechanisms (taxes, permits, tolls) to internalize environmental costs. However, social issues, such as poverty or social vulnerability, are hardly ever part of this perspective. In contrast, "strong" eco-modernization seek not only to minimize the production of risks but also to prevent their unfair externalization in space and time; and as a result, highlights social and political aspects linked to the environmental conflict (Dryzek 1997; Hajer 1995; Christoff 2002).

Strong Eco-modernization constructs the world as a socio-biological system with geographical flows of resources and pollution between poor and affluent regions and countries. Injustice prevails, since resources tend to migrate from the poorer to the richer areas whereas pollution tends to flow in the opposite direction. Thus, the discourse calls for the implementation of changes to existing political and economic systems that encourage fairer geographical and social distribution of producers and recipients of pollution and wealth.

The practical implications of corporate strategies related to the "strong" ecological modernization ideas tone down ideas of distributive injustice. Instead these ideas focus on transformative environmental management strategies and tools which are linked to a new model of industrial production, and which go beyond minimizing impact at the firm level (cleaner production) or the value chain (product stewardship). These strategies take into consideration the interaction and flow of materials and energy between industries and use the natural world as a model to redesign environmentally sustainable industrial processes.

Strong Eco-modernization strategies include 'Industrial Ecology', 'Natural Capitalism' (Hawken et al. 1999), Cradle to Cradle (McDonough and Braungart 2002), or Biosphere Rules (Unruh 2008). "Industrial ecology" proposes "industrial metabolism" (where one industry's waste is the next one's raw material) and "dematerialization" (reduction in the use of materials and the production of goods that are both more durable and better supported by other services across their longer life cycle). Natural Capitalism (Lovins and Lovins 2001) adds to the principles of eco-efficiency and dematerialization, the necessity for investing in the preservation of natural capital and in ecologically responsible companies. "The biosphere rules" (Unruh 2008) explains that manufacturers must design their products at molecular levels, minimizing the number of chemical compounds and raw materials which can later be 'up-cycled' for new uses without losing quality (carpets where the base is recycled and the fibres are reinserted again and again).

'Cradle-to-cradle' (C2C) product design (McDonough and Braungart 2002) rejects eco-efficiency and waste minimization, and advocates eco-effectiveness and sufficiency as alternative principles. "Waste is Good" is the motto underpinning strategies aimed to redesign industrial processes with closed loops of producer goods and energy (McDonough et al. 2003), where the important thing is not to reduce waste, but to ensure the production of enough waste to be used as producer goods in the next industrial context, thus granting a continuous use and reuse of matter and energy (van der Pluijm et al. 2010). Cradle-to-Cradle is a very popular concept in some parts of the world. Cradle-to-Cradle is based upon the same premises as green growth: creating a positive value instead of remedying damage or minimizing impact (Bjørn and Hauschild 2011).

"Strong" eco-modernization intervention strategies are gradually being accepted by proactive companies embracing corporate sustainability (Halme 2002). Arguably, they represent an innovation in environmental management philosophy that could steer game-changing Green Growth.

Although environmental sustainability has been gaining prominence in the public and political arenas, there is still a disconnection between discourse and practice. With some remarkable exceptions,[4] western sustainability concerns have not been consistently translated into substantive progress toward Green Growth initiatives (Berkhout et al. 2010). Sustainable Development's emphasis on balancing economic, social and environmental growth has proven very difficult to convert into concrete policy objectives**.** Economic growth has remained the primary objective of much economic policy (Jackson 2009). For years there has not been enough political commitment to modify the prevailing model of production and consumption. As twin concepts, regulatory and industry standards, and consumer oversight, can be considered as the 'race to the top' stimulus in the governance of environmental issues in the European Union over recent decades. However, they had not been effective in forestalling the threats of climate change (Stern 2007). For many, 'Green capitalism' can't be achieved by a change within the western materialist values and lifestyles that underpin the market system (Luke 2008; Seyfang 2001). In turn, such change will not be generated from 'within' the system, since any ad-hoc solutions precipitate new problems through the pursuit of endless profit.

1.4 Green Growth

Recently, a new wave of political interest in understanding how 'growth' can go hand in hand with 'green' has occurred in the midst of the worst economic crisis for decades; this situation adding to a growing consensus that Global warming is a definite danger to the fate of the earth. The economic crisis is highlighting the exhaustion of the economic model, thus providing a trigger to move fast into an alternative system to give sustainability a clear 'policy and economic' focus. Enter Green Growth

According to United Nations Environment Programme (UNEP), 'Green Growth' is a policy focus for East Asia that emphasizes environmentally sustainable economic progress to foster low-carbon, socially inclusive development.

[4] For instance, the End-of-Life Vehicle and Waste Electrical and Electronic Equipment (WEEE) Directives, enacted by the European Union that makes manufacturers responsible for automotive and electronics materials disposal. Another case in point is the Registration, Evaluation and Authorisation of Chemicals (REACH) normative. REACH extends producers' responsibility downstream the supply chain and makes manufacturers and importers of chemicals responsible for providing information and implementing risk management measures.

In Europe, policy-makers in countries such as Denmark, Germany, Norway and France have favoured the term ‘Green Economy’ to promote similar policy ideas. Although there are differences between European and Asian ‘green policy foci’, these are more a reflection of differences in cultural values and prevailing economic system (market socialism in Europe, developmental capitalism, or the Development State model in East Asia). Both the ‘European Green Economy’ and ‘Asian Green Growth’ are policy perspectives currently being promoted by the Organisation of Economic Cooperation and Development (OECD) and the UN under the discourse of ‘Green Growth’/Green New Deal’ as a new paradigm that enables economic growth while enhancing sustainability and promoting social inclusion (OECD 2009a, b; UNEP/ILO 2008).

Green Economies include energy markets, development of natural capital (i.e. planting and managing forests that conserve soil and water supply), clean and sustainable production, environmental innovation (i.e. fuel-cells, carbon-capture & storage, new materials), and further development of service sectors (Hamdouch and Depret 2010). However, the main driver for the promotion of Green Growth is not ecological but economic. Green-Growth is proposed as a post-financial remedy to reinvigorate the ailing global economy, refocusing it towards investment in markets for environmental goods and services, and the development of ‘natural infrastructure’ such as forest, water bodies, bio-diversity (Lane 2010). These new ‘environmental industries’ should be the source of low-carbon, socially inclusive growth, tackling climate change actions and triggering both high-skill intensive employment – R&D in clean energy technologies – and low-skill intensive employment (for instance in forest planting, and organic agriculture).

In inter-governmental negotiations, the concept is being supported by the EU, Japan and other developed countries (Hamdouch and Depret 2010; Luke 2008) and increasingly championed by transitional economies such as South Korea, India, Brazil and China (Berkhout et al. 2010; Zapata et al. 2010). This interest is explicitly reflected in the political agenda of these countries – most noticeable in the EU’s ‘Green Economy new deal’, Japan’s ‘New National Energy Strategy’, and in Korea’s ‘National Green Growth Strategies and Environmental’ policy, a state-led strategy for global competitiveness where flagship Green Growth strategies have been put at the heart of its blueprint for competiveness. This strategy is critically analysed in Chap. 2 of this book.

The OECD agenda for Green Growth is firmly grounded in neo-classical economics and focused on the correction of imperfections affecting markets for environmental goods and services. In the OECD’s Green Growth Framework (2009b), environmental deterioration results from externalities and market imperfections creating obstacles to the free interplay of market forces. Correcting for these externalities can improve welfare and is therefore socially and economically efficient and desirable. From this perspective, there is not necessarily a trade-off between promoting wellbeing and ensuring environmental quality. Regulatory intervention is needed to render markets for environmental goods and services closer to perfect operation. Industry standards, green customers and voluntary efforts are not enough on their own to transform the economy and provide renewed direction to environmental and economic policy in the tradition of sustainable development.

The OECD argues that Green Growth is a policy oriented spin-off of sustainability that resolves the latter's operational ambiguities and provides practical solutions to urgent problems (OECD 2009b). Although the focus is on policy, the OECD (2009b) acknowledges that "some businesses have started to explore more systemic and radical green innovations involving new business models and alternative modes of provision. Businesses that perform well on radical innovations are also better aligned towards green innovation".

In terms of discourse, the OECD's 'Green Growth' represents a small step back towards 'Environmental Problem Solving': orthodox environmental economics, reliance on public bureaucracies and markets, top-down, state led policy, even acknowledging that some 'trade-offs' cannot be avoided (for instance between intragenerational and intergenerational equity).

Green Growth, however, could be more than a rebranding of traditional neoclassical economics applied to environmental good and services sectors with a stronger focus on environmental and social innovation. Green Growth policies could aim to be game-changing and provide transitional platforms towards structural changes in the economy (Torgerson 2001; Fritz-Morgenthal et al. 2009). The question is no longer whether the current capitalist model should be replaced by 'Green Growth', but if the structural conditions required for economic growth can be compatible with environmental sustainability and how the transition to the new economy should be managed. In order to do so, national strategies should be open to debate a range of issues related to this transition. Some of these issues and debates include:

- How growth should be defined and progress towards green growth measured; -and how can we account for environmental deterioration in such measurement?
- Is there a possibility of a capitalist economy adapting to a long-term zero-growth situation?
- What are the limits of technological innovation to decouple economic growth from environmental impact?
- How will the social impacts of job losses in more polluting industries be managed?
- How can the existing institutional disincentives for Green Growth be changed – including pricing structures, taxation system and consumption patterns?
- What are the political and cultural barriers to create and implement systems of incentives facilitating green growth?
- What is the right balance between regulatory intervention, market mechanisms and the third sector?
- What is the role of voluntary approaches both in small and large enterprises?

In the next section these issues are grouped into interrelated dimensions and drivers, outlining an integrative framework that will help tie the chapters together and the issues facing Green growth.

Table 1.1 An integrative framework for Green Growth analysis

Dimensions	Challenges
1. Quality of growth	Greener Growth or truly Green Growth?. How is Green Growth measured? Is there a possibility of a capitalist economy adapting to a long-term zero-growth situation?
2. Policy integration	How can the existing institutional disincentives for Green Growth can be changed – including pricing and taxation structures, financial systems and consumption patterns? How will the social impacts of job losses be managed?
3. Multi-stakeholder governance	Administrative sphere or multi-stakeholders governance? How can different scales of governance be coordinated? How can we surmount political and cultural barriers?
4. Flexible regulation and dynamic policy mix	How can we design a smart regulatory package that is dynamically relevant; allowing for flexibility and leveraging green investment? What structural conditions are required to make environmental regulation a source of market creation and technology development? What is the right balance between price signals and non-price policy? How can policy be made dynamically relevant to changes in the environment?
5. Competitiveness	Are national 'green' competiveness and global Green Growth compatible? How can governments influence trans-boundary supply chain competitiveness
6. Virtuous cycles: adding value	How can we reconceptualize trade-offs to design virtuous circles between growth, environment and poverty alleviation, efficiency and effectiveness, consumption and protection of natural ecosystems, formal and informal economies
7. Inclusion, justice and social cohesion	What mechanisms do we need to assure that green growth is accompanied by increases in environment and distributive justice?
8. Trust and collaboration	How can trust be created, maintained and reinforced in collaborative relations? To what extent can relations of trust and collaboration between companies and governments become a disincentive for harder regulation? What is the role of voluntary approaches both in SMEs and MNEs?
9. Entrepreneurship	How can we harness entrepreneurship potential to develop Green innovation? What is the right balance between regulatory intervention, market mechanisms and the third sector?

1.4.1 Green Growth Dimensions

Table 1.1 outlines some important interrelated dimensions underpinning the conceptualization of Green Growth and the administration of transitions to a new economy. These dimensions include quality of growth, policy integration, multi-stakeholders governance, flexible regulation, competitiveness, dynamic policy mix, social cohesion and inclusiveness, trust and collaboration and entrepreneurship. The challenges highlighted relate to the 'inputs' and 'outputs' of Green Growth policy. The first dimension 'Quality of Growth' (already discussed in the previous sections) is the dependent dimension or ultimate aim of Green Growth.

1.4.1.1 Policy Integration

To promote Green Growth the OECD (2009b) recommends a policy mix with instruments covering both demand and supply. This mix should include price and non-price policy tools. Price policy tools encompass a variety of economic instruments such as environmentally-related taxes, fees and charges, tradable permits, government spending in green technologies and natural infrastructure, and elimination of environmentally harmful subsidies. Non-price policy tools include command-and-control regulations, non-price policies to support green technologies and innovation (training, network formation and research), and voluntary approaches based on negotiated agreements between the government and specific industrial sectors to address a particular environmental challenge.

An effective policy mix will have to draw on both sets of tools giving more weight to tools according to circumstance (also a consideration for flexible and dynamic regulations). In the OECD-UNEP perspective, price policy tools and economic instruments are the most important drivers of Green Growth, closely followed by commands and control approaches and non-price policies to support green technologies. However, the role of environmental management in Green Growth strategies is potentially more relevant than envisaged by OECD, with truly proactive companies moving ahead of policy. This vision is because the perspective offers little more than a selection of tried and tested tools and instruments, but nothing of an innovative quality (OECD 2005, 2008, 2009a, b).

Many of these policies may still be controversial (patents, removal of subsidies) and some inconclusively supported by empirical evidence. Longitudinal analyses and case studies of the effects of Green Growth policies are particularly scarce. In addition, the strategies tend to emphasize a national focus, while being less specific in terms of how to organize global actions; despite the global nature of the problems they aim to address.

1.4.1.2 Multi-stakeholder Governance

The integration of a policy sector focus – environment, innovation, competitiveness, housing, energy, agriculture, building environment (Hamdouch and Depret 2010) and scales of intervention (Marsden et al. 2010) are important. Green Growth requires integrated strategy at national and international levels which, if successfully implemented, will lead to environmentally sustainable growth. The targets of many of these green policies include a range of Small and Medium Enterprises (SMEs) as well as the large businesses (as illustrated in this book).

The governance of environmental issues is a complex and contested system that is dynamically constructed by public, private and consumer interests operating at a variety of spatial scales, local, national, regional and global (Marsden et al. 2010). Governance of Green Growth policies at the global scale need to take into account the wider context with implication for global Green Growth clearly identified. Analyses also needs to include the extent possible negative effects are passed on to the wider context. For example, national or regional economies can become greener by successfully exporting the more polluting parts of the economy, thus hindering global Green Growth. In this context, national regulations are increasingly impotent for regulating cross-border supply chains (Dicken 2007).

Even within the confines of national territories, the regulation of supply chains is becoming more volatile and contested in the face of natural and financial resource pressures and potential repercussions in terms of food scarcity, energy security, and contested environmental quality and associated demands for greater social equity in relation to the environment. At the other end of the spatial scale, local communities have been drivers of green technologies in California and Germany. However, they have also acted as strong barriers to the dissemination of particular innovations such as wind energy in Norway, France and Japan (Hamdouch and Depret 2010).

Nel et al. (2009) conclude that for groundwater contamination the cost of integrating the considerations of some stakeholders, such as the local community, is much less than the cost of having to assume responsibility at a later date for repairing environmental damage. Oikonomou et al. (2009) have proposed that the explicit participation of the local community, with initiatives such as wind farms, should be compulsory, as it avoids possible drawbacks, free riding and conflicts from the outset. Indeed, local communities and their gatekeepers may play an important role in sustainable resource management. Both extremes of the governance scale, global and local, are influenced by informal economies, embedded in communities as a domain of integrated, personalized life activity.

Community relations and informal arrangements are obvious at the local scale but also dominant in global interactions. For example, social networks allow unbounded interpersonal communication – that is, real time exchanges creating virtual communities that extend beyond the constraints of geographical and organizational boundaries, (Dicken 2007).

To strategically evolve from the present to the most desirable Green Growth future requires (spatially) multi-scale, multi-level (macro, meso and micro), trans-sectoral, multi-stakeholder governance initiatives which align government policy and 'stimulus' packages with the promotion of behaviour change in market behaviour (Marsden et al. 2010; Jänicke 2008; Hamdouch and Depret 2010; Smith 2007).

1.4.1.3 Flexible Regulation and Dynamic Policy Mix

As argued in Chap. 3, environmental regulations can hinder economic growth by imposing higher costs on firms. Alternatively, regulations can stimulate growth by creating demands for green products and services, incentives for green technology innovation and opportunities to capitalize on emerging markets.

The relationship between regulation and competitiveness at the firm level provides further support for using regulation to stimulate improved environmental performance by industry. This relationship is even more evident in the Asia Pacific region “l’usine du monde” (Lane 2010) where moves towards clean energy and production are even more necessary due to resource limitations.

“Green success” can typically be achieved when both flexibility of commitment and leveraging potential are strong (Rugman and Verbeke 1998). When firm resources are scarce the incentives to improve environmental performance through environmental commitment are higher (i.e. cost saving through improved efficiency). In turn, when the firm’s environmental regulatory setting is weak, the flexibility of commitment is strong. However, stringent regulation can also result in increased competitiveness if the leveraging potential is strong.

In these situations proactive companies seeking first-mover advantages would lobby for the adoption of their environmental performance standard as an industry standard. An appropriate design of Green Growth regulation will allow for leverage and initial flexibility. For instance, by setting stringent standards but allocating limited resources for enforcement. Chapter 7 analyses the consequences of this flexible approach in China. The Korean Green Growth strategy seems to be a sequential approach to regulation, leaving some areas deliberately under regulated, then ‘raising the bar’ as pro-active companies move beyond regulation.

Green Growth is considered to be a dynamic national strategy, which uses environmental regulation as a source of market creation and technology development. The discourse of Green Growth sends a powerful message to companies operating in poorly regulated countries. Seize the opportunity and invest in environmental innovation to reap green success benefits while the environmental regulation is still weak, and find yourselves in a leadership position when environmental stringency increases.

1.4.1.4 Competitiveness and Green Opportunities

In the most desirable ‘Green Growth future’, the global economy has successfully exploited the opportunities for transformation and renewal offered by the environmental crisis. We should see how such opportunities are conceptualized at each level of governance.

The macro-level of governance refers to national and supranational policies. A key driver of Green Growth at the macro level is the race to improve competitiveness. Competitiveness is advocated as the recipe for growth at the firm, national and global level (Porter 1990; Wuben 2001; Sagheer et al. 2009) thus conciliating national and supranational interests. Country competitiveness can be defined as the ability of a nation to produce goods and services that meet the needs of international markets while maintaining or expanding real incomes (Waheeduzzan and Ryans 1996). Interestingly development of stringent environmental regulation can be viewed as an effective path to improve national competiveness (Porter 1991). The economic crisis has brought a revival of Keynesianism and deficit spending on an immense scale (Stiglitz 2010). The OECD (2009b) and UNEP explicitly promote Government funded stimulus packages to develop environmental goods and services sector as a way out of recession through improved competitiveness. Nowadays, Green markets have an estimated value of $1370 billion, which is forecasted to double by 2020 (UNEP/ILO 2008). Competitiveness drivers in the green goods and services sectors are e.g. costs, quality, food safety, technology and coordination, pricing and import conditions (Sagheer et al. 2009).

The meso-level of governance includes industry and firms. The meso-level has a profound influence on Green Growth. Sectoral competitiveness is a critical link between business and national competitiveness (Traill and Pitts 1998). Schumpeter (1975) emphasizes that economic growth is administered by the state but driven by the capitalist enterprise. At this level, Green Growth will still be driven by the quest for profit, more specifically profiting from ecological crisis through the exploitation of green markets (Luke 2008).

As alluded to above, regulatory stringency in a country may produce a reduction in 'dirty' growth, only because the polluting industries have been exported to poorer regions which are seen as "pollution havens". However, the evidence supporting the pollution havens theory is weak (Wuben 2001). Large Multinational Enterprises (MNEs) with global supply chains are in a better position to control negative spillovers that go beyond the limits of government policy. In the absence of a supranational organization controlling MNEs, the only way forward is increased commitment of business to become voluntarily responsible for the life cycle impacts of its products and increased pressure of civil society to transform policy and business models accordingly.

1.4.1.5 Virtuous Cycles: Adding Values

The most differentiating feature of Green Growth is the emphasis placed on the design of policy and innovation to create virtuous cycles. Economically, Green Growth strategies should aim to break the vicious cycle between environmental deterioration and unsustainable economic growth-poverty, and replace it with a virtuous cycle of quality growth and environmental enhancement (i.e., climate action, energy security, sustainable housing).

A more radical approach to Green Growth would include the establishment of virtuous cycles between the formal economy, driven by the 'possessive individual' and informal economies driven by communitarian values and social networks (Torgerson 2001).

Operationally, virtuous cycles between Green Growth policies and developmental programmes should be pursued. From a stakeholder's point of view, multi-stakeholder governance should endeavour to create virtuous cycles between the interests of different stakeholders' groups (for instance workers in industries phased out should be retrained to work on new sectors).

From a spatial perspective, activities exported abroad by MNEs generate a 'halo effect' improving the environmental capabilities of local enterprises, and this in turn provides a stimulus for local entrepreneurship further tapped by MNEs through partnerships and networks. Finally, from an industrial ecology point of view, virtuous cycles should be generated between flows of waste and flows of inputs along the supply chain and across industries, and between industrial and natural systems (i.e., waste that can be composted generates nutrients for agriculture and bio-fuel crops that thrive in symbiosis with local biodiversity).

1.4.2 Inclusion, Justice and Social Cohesion

Social cohesion is the 'glue' that holds society together. Given that social capital and high social cohesion predicts economic success – although the reverse is not necessarily true (Putnam 1993). Sustainable economic policy must explicitly seek to reinforce social cohesion (Lépineux 2005). Otherwise, society risks a divide that creates conflict and hinders the ability to collaborate in a shared vision. Inclusive, equalitarian and just policy develops social cohesion, in turn a necessary structural input for the success of game-changing policies that affect the alignment of power between social groups.

Social cohesion has been an explicit objective of Korea's developmental strategy and the 'glue' that sustained the Korean's model of inclusive growth (i.e. the 'Korean miracle' of achieving growth while reducing inequality) (Stiglitz 2010). Green Growth as a new paradigm should enable economic growth while enhancing sustainability and promoting social inclusion. Poverty alleviation and reductions in environmental and social justice should be implicit aims of any Green Growth policy mix.

1.4.3 Trust and Collaboration

Trust is a key concept underpinning voluntary agreements, green consumption and multi-stakeholders governance. An effective way to conceptualize multi-stakeholders governance is through deliberative democracy (Habermas 1996): the use of dialogue and reasoned argumentation to foster mutual understanding, delivering collective decision-making through the best possible genuine democratic decisions, reflecting the diversity of interests and minimizing the interference of political power, money or strategising (Scherer and Palazzo 2007; Dryzek 1997).

Habermas (1996) distinguishes between *strategic action*, which is based on the skilled use of power relations to achieve specific goals and *communicative action*, based in the use of dialogue and communicative ethics. Game-changing policy cannot rely in pure strategic action to achieve its goals without risking social turmoil and resistance. It needs communicative action to build consensus and social cohesion. A crucial condition for the success of communicative action is 'trust': actors must consider themselves mutually accountable and ready to take on obligations arising from agreements. Trust is built through repeated interactions creating an 'ideal speech' where actors learn how to mean the same thing by the same words, and arguments supporting a mutually acceptable solution were not found to be false or mistaken. Trust is the basis of genuine voluntary agreements and environmental policy should create the conditions for conflict resolution through communicative acts and democratic decisions. In turn, trust underpins the acceptance of unilateral policy actions born out of a need to act fast to address an emergency. Trust between the government, companies and communities are strong when it has been reinforced by a history of mutually beneficial and truthful communicative actions such as in the case of Korea. Chapter 2 discussion suggests that trust between companies and government is the basis of the success of Korea's Green Growth National Strategy; which relies heavily on voluntary compliance with government 'guidelines'.

1.4.3.1 Entrepreneurship

Sustainable entrepreneurship is the process of discovery, evaluation and exploitation of the economic opportunities present in market failures which hinder sustainable development – and so reduce environmental degradation. Environmental problems can be seen as results of unregulated market imperfections entrepreneurs have the velocity of response and innovating capacity needed to create business opportunities to address market imperfections, Therefore, by simply supporting entrepreneurs to exploit the inherent opportunities associated with poor environmental performance and need for environmental technology can help to move the global economy towards Green Growth.[5]

For entrepreneurs to be able to exploit the opportunities arising from a shock (e.g. a radical environmental regulation), there must exist certain barriers that prevent other stakeholders (for instance, large firms) from taking advantage of those opportunities (Dean and McMullen 2007). Bruggman and Prahalad (2007) explain that, in vulnerable social systems, such barriers are the lack of information within large firms about the dynamics of social systems in the affected communities; where perceptions of risk, adaptive capacity, and social acceptation are key points to define the acceptance of a new product. Therefore, engaging vulnerable stakeholders' in an entrepreneur's initiatives and building partnerships with large firms can bring resources to the communities and help firms overcome barriers to opportunities.

Companies looking to invest in eco-innovation and emerging green-markets need to develop partnerships with local entrepreneurs to build competitive supply chains or

[5] Similarly, The United Nations Commission on the Private Sector and Development (UNCPSD) thinks that promoting entrepreneurship can be a more effective solution for global poverty than economic humanitarian aid. The commission reckons that the existence of entrepreneurs, adequately sponsored by a solid institutional framework, fortifies all dimensions of adaptive capacity, creates opportunities for saving, employment and innovation, taking into account local conditions, and integrates marginal groups although it can potentially reduce the natural capital (UNCPSD 2004).

to enter markets. In turn, a competitive supply chain is crucial for ensuring a sustainable distribution of value added along the chain, thus contributing towards raising its overall competitiveness (Sagheer et al. 2009).

Collaboration between large firms and entrepreneurs may result in stable joint benefits to firm and community, and primarily a shared accountability of the problem, and shared vision of solutions. Sometimes it is possible to transform the problem domain itself or to generate new knowledge that results in new product development or efficiency improvements (Bowen et al. 2010; Harrison et al. 2010). Green Growth requires institutional entrepreneurs and political entrepreneurs (government employees who can modify subsidy or tax systems) who can influence the political and economic systems, and are the most appropriate stakeholders to integrate within the companies' alliances (Dean and McMullen 2007).

1.4.4 Green Growth Drivers

The transition dimensions are in turn intertwined with three core drivers or engines of Green Growth: innovation (technological but also social); globalization (economic but also cultural and institutional); and ecological urgency.

Globalization refers to a series of qualitative and quantitative processes of changes in cross-borders flows of goods, services, capital, knowledge and people. Technology is one of the key processes underlying economic globalization, and both globalization and technology are related to the spread of trans-boundary pollution and economic growth (Held and McGrew 2007). According to Kondratiev waves' theory (Dicken 2007) economic growth evolves in a series of long-waves (k-waves) – each of 40–60 years duration, each associated with a particular technological innovation that propels the economy and incrementally changes the prevailing techno-economic paradigm.[6] The prolonged financial crisis and recession that started in 2008 might be signalling the depression phase of the k-wave started in the 1980s by Information and Communication Technologies (ICTs). Thus, Green technologies could be the engine of the sixth k-wave, one that paired with increased social awareness of ecological urgency will displace the current set of growth-oriented techno-economic practices. Encouragingly, Green innovation is growing at different levels in developing countries. In particular, grass-root innovation that offers potential for south-north collaboration and reciprocal knowledge transfer.

The interaction between the nine transition dimensions and three drives will result in a variety of possible trajectories, more or less successful, towards a Green

[6] Each wave has a particular geography and follows four distinctive phases: prosperity, recession, depression and recovery. Industrial society has passed through five waves so far. The last two k-waves were 40–80s era of Fordist mass production (in the USA, Germany, Japan, Switzerland, Australia) and the Information and Communication K-wave that started in the 1980s and is now entering its fourth decade (in Japan, USA, Germany, Sweden, Korea, Taiwan, Canada) (Dicken 2007).

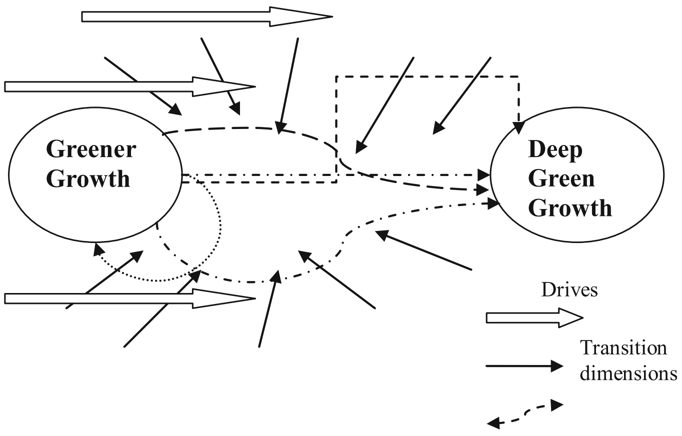

Fig. 1.1 Green Growth transitions

Growth economy. Figure 1.1: Green Growth Transitions, combines the concepts summarized above with socio-technical transition theories (Berkhout et al. 2010), and aims to summarize the integrative framework. Such a framework proposes that the current policy-mix and strategies are only the initial stage (Greener Growth) in an evolutionary economy moving towards Green Growth. This may evolve along a variety of alternative patterns associated with technical change and characteristic forms of economic organization, competition and cooperation. The final configuration of such trajectories will depend on the dynamics between the drivers of Green Growth and the transition dimension. This is not a sudden process but one that happens gradually until a new paradigm crystallises.

In this section, the main elements of our Green Growth framework were outlined, we now provide a summary overview of the book's contents to help the reader relate this framework to the following chapters.

1.5 Introduction to the Content of the Book

Since the book covers a multi-disciplinary topic with a variety of levels and dimensions to be examined, its content and organization could have been presented in numerous ways. Table 1.2 provides the various concepts and issues examined by the authors that helped guide our categorization and organization of the Green Growth framework.

Our book seeks to touch three converging and complementary dimensions of Green Growth: the policy oriented macro-level of governance and the managerially oriented, meso-level and micro-level of governance. Our framework argues that for Green Growth to be a step forward from "conceptual sustainability" into game-changing practice, policy and management should attempt to unleash synergies between environmental investments and economic performance.

Table 1.2 Overview of book chapter and dimensions of Green Growth covered

Chapter title	Stakeholder focus/issue	Level/scope	Method	Dimensions of cG/*Issue*
2. A Critical Review and New Policy Framework of the Low-Carbon, Green Growth Strategy of Korea	Government *Policy* *Environmental strategies*	Macro/National (Korea)	Policy analysis	Quality of growth integration governance Regulation Competitiveness/Social cohesion Trust
3. Greening the Korean stacks through lessons from the EU Emission Trading System: A Socio-legal Analysis	Government and Industry *Policy* *Climate change* *Economic instruments*	Macro/Supra-national EU and Korea	Policy analysis	Governance Regulation Competitiveness Integration Social cohesion Trust
4. Sustainability Science Integrated Policies Promoting Interaction-Based Building Design Concept as a Climate Change Adaptation Strategy for Singapore and Beyond	Government and Industry *Policy* *Climate change* *Built environment* *Sustainability science*	Macro/National (Thailand)	Delphi Study	Integration Regulation Governance
5. Analysis of Environmental Productivity Using the Meta-frontier –Manufacturing Industries in Korea and China	Industry, indicators *Green technologies* *Productivity* *Efficiency*	Meso/Supra-national (Korea and China)	Empirical Longitudinal analysis	Competitiveness
6. Green Growth Index and Its Policy Feedback	Government *Indicators* *Green growth* *Green welfare*	Macro/National (Korea)	Dynamic Modelling Longitudinal analysis	Quality of growth Regulation Integration Competitiveness
7. Measuring the Environmental Impact of Automotive Supply Chains: A Korean-European Case Study	Industry *Environmental impact-climate change-supply chain strategies*	Meso/Supranational: Korean-European supply chain	Case study Longitudinal analysis	Governance Competitiveness

(continued)

Table 1.2 (continued)

Chapter title	Stakeholder focus/issue	Level/scope	Method	Dimensions of cG/*Issue*
8. Strategic Responses of Multinational Corporations to Environmental Protection in Emerging Economies: The Case of the Petroleum and Chemical Sectors	Government and Industry *Environmental* *Performance* *Env standards and Env enforcement*	Meso/Supranational: China, Taiwan, Colombia and Peru	Multi-methods; Case studies, survey	Regulation Governance/Integration
9. Sustainability Innovations and the Impact on Performance of Japanese Automotive and Electronics Companies	Industry and Gov *Environmental performance* *Environmental reporting*	Meso/regional and supply chain	Empirical Longitudinal analysis	Regulation Integration Competitiveness Virtuous circles
10. Achieving Greener Growth: A Business Perspective for Proactive Commitment	Industry *Lean and green innovation*	Micro/firm (UK)	Case Study	Competitiveness Virtuous circles Entrepreneurship
11. Participatory Research on Green Productivity of Silk and Cotton Woven Products in Northeast Region Thailand	Government, Industry (SMEs) Local Authorities, Universities, community *Environmental technologies-sustainable livehoods*	Meso/programme (Thailand)	Action research	Entrepreneurship Governance Inclusion, social cohesion
12. Attitudes Towards Energy Efficiency and Renewable Energy in European SMEs	Industry (SMEs) *Renewable energy* *Energy efficiency*	Micro/firm	Survey	Governance Integration Entrepreneurship
13. The Diffusion of Green Technological Innovation and the Stimulus: the Technological Evolution of Lubei Eco-industrial Park in China	Industry *Green technologies, path dependence*	Meso/regional (Lubei China)	Case study Longitudinal analysis	Regulation Competitiveness Regional governance Integration

14. The Practice of Innovative Energy Systems Diffusion in Neighborhood Renovation Projects; A Comparison of 11 Cases in the Netherlands	Industry Local authorities Households	Micro/households Meso/regional policy	Case studies	Governance Regulation Integration
15. Why Consumers Buy Green. The influence of Eco-labels in Green Consumerism	Customers, government, firms *Green consumption* *Green labels*	Macro/Green consumption Micro/Customers Purchase decision	Survey	Governance Integration Trust
16. Conclusion	Summaries, discussion of findings	Macro, meso, micro	Thought piece	All. Re-conceptualization of Green Growth

Since we are focusing on a multi-level, multi-stakeholder governance perspective, we have defined the major stakeholders involved in each chapter. The selection of chapters also aims to provide insights into the main areas where transitions should be consistently managed: national and regional government policies at the macro level (Chaps. 2, 3, 4, 5, and 6); industry-wide and global business practices at the meso level (Chaps. 7, 8, and 9); and medium and small businesses' initiatives at the micro-level (Chaps. 10, 11, 12, and 13) and household consumption (Chaps. 14 and 15). Another noteworthy characteristic is the use of multiple scales of analysis, notably geographic region and organization/institutional characteristics (e.g. supply chains).

Overall, the relation between Competitiveness, Technology and Green Growth is the backbone of this book and is addressed in Chaps. 2, 3, 5, 6, 9, 10, and 13. Issues of integration and governance are addressed in Chaps. 2, 4, 6, 7, 8, 11, and 12. More specifically, Chap. 2 proposes a detailed Green Growth framework for Korea and emphasizes that low-carbon, green growth strategies make sense when resources are scarce but they need many disruptive changes in business and technology platforms that regulation alone cannot deliver. Chapter 13 analyse technological transitions. It highlights that disruptive technology change is facilitated by shifts in the wider socio-economic environment, (i.e. favourable policies, auxiliary technological support, market environment, corporate culture and resources endowment.).

Chapter 8 fully supports the 'Green success' condition, noting that when MNCs perceive good environmental performance can assist in creating competitive advantage in a host country's market, they are more prone to deploy resources, environmental capabilities, and experiences based upon their global policies and practices. Chapter 5 observes that the Korean manufacturing industry with a focus on productivity is better positioned to benefit from Green Growth than Chinese manufacturers with a focus on efficiency. Chapters 9 and 10 provide quantitative and qualitative evidence of mutually beneficial relations between environmental innovations and economic performance. The importance of trust in Green Growth policy is highlighted in Chaps. 2 and 15, while the existence and mechanics of virtuous cycles are discussed in Chaps. 9 and 10.

Entrepreneurship is analysed in Chaps. 10 and 11. Chapter 10 observes that green entrepreneurship is influenced by dynamic contingencies including regulation and customers' preferences. Chapter 11 analyses entrepreneurship in the semi-informal economy, through an action-research programme aimed to 'green the informal economy and livelihoods of textile entrepreneurs. It concludes that successful synergies between entrepreneurship, Green Growth, poverty alleviation and sustainable livelihoods are more difficult when intermediate organizations such as local authorities are not involved. Only Chap. 11 has social cohesion, inclusion and justice at its core, although the chapter does not make it explicit. Passing mentions to poverty and issues related to social cohesion are included in Chaps. 2 (which comments on Green Growth strategies to end energy poverty in South Korea), 8, and 14.

So welcome to the book and the important ideas that are within it. They provide substantial insights for managers, policy makers, and other stakeholders. We hope you find the chapters enjoyable and useful. We will meet you again in the concluding chapter.

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Chapter 2
A Critical Review and New Policy Framework of Low-Carbon, Green-Growth Strategy of Korea

Seung-Kyu Rhee, Dae-Chul Jang, and Younmin Chung

Abstract The Korean government recently announced the official national greenhouse gas (GHG) emission reduction target, which is to cut carbon emissions by 30% from its business-as-usual (BAU) level forecast for 2020. In this chapter, we critically review the contents and processes of the low-carbon green growth national strategy as it has existed up to now, and then suggest a new framework to help realize the ambitious vision and the goals.

This chapter summarizes the prominent characteristics of the contents and processes of the national strategy based on critical reviews of all the relevant governmental and private responses. The results from this case study enable us to propose a new framework for the development and evaluation of national low-carbon, green growth (LCGG) strategies. We focus on various stakeholders who can compete against and cooperate with other players in the game. The dynamic interaction involves both the top-down and bottom-up drivers of change. Also we propose that a national LCGG strategy should incorporate the policy effects not just within the country borders, but also on the global supply chains. LCGG strategies require many disruptive changes in business and technology platforms. There are huge uncertainties in the competition among alternative platforms. We propose a multi-sided market competition model to help analyze the dynamics of this phenomenon. The evolutionary progress toward a global standard will determine the performance of these efforts.

Keywords Climate change policy • Multi-sided market competition • Korea • Global supply chains • Sustainable consumption and production

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2.1 Introduction

After the Bali Action Plan of 2007, it was apparent to the Korean government that Korea can no longer afford to keep silent about its reduction goal for GHG emission. Facing the 15th COP in Copenhagen, the newly inaugurated Lee Administration in early 2008 announced that Korea would prepare a comprehensive national strategy for a low carbon society. In June 2008, President Lee Myung-bak promised at the G8 Summit that Korea would announce its emission reduction goal by 2009. President Lee went further during his national address on the Korean Independence Day, August 15, 2008 by saying that clean energy and green technology would be the growth engine and source of new jobs in his new economic policy.

With strong commitment from the top, the entirety of Korean society began to move in this new direction. Low-carbon, green growth became magic words that attracted talented people and ideas from all corners of the nation. All levels of the government, businesses of all sizes, think tanks, research and education institutes, and the media have all joined the crusade. The effort resulted in the official national GHG emission reduction target of November 17, 2009, which is to cut carbon emissions by 30% from its BAU level forecast for 2020. In this chapter, we critically review the contents and processes of the low-carbon green growth national strategy as it has been developed up to now, and then suggest a new framework to help realize the ambitious vision and the goals. To our knowledge, this kind of integral analysis and review has not previously been undertaken. We hope that this work can provide new ideas for practitioners to exploit in developing and implementing the national LCGG strategies in coming years.

2.1.1 Green Growth Strategy: The Context

The average rate of temperature increase in Korea during the past century is far greater than the world average (1.7° increase from 1912 to 2008). This shows that the Korean peninsula is being directly influenced by climate change. According to a report by the Presidential Committee on Green Growth (PCGG), winter is now 22–49 days shorter and heavy rain and hot temperatures are prevalent during summer. Also 2,127 people died due to heat waves that occurred from 1994 to 2005, and 2,227 more incidents of malaria infection were observed in 2007. This experience, combined with international pressure, gave the new administration strong motivation to make it climate change a national priority. President Lee's initiative, called the LCGG strategy, was the response to the challenge. Green growth is defined as sustainable growth in which reduction of GHG and environmental pollution is the key target. Green technology and clean energy are key drivers for creating new growth potential and jobs.

UNEP (2009) summarized the background motivation for the new Korean strategy as follows: (1) the insecure energy supply structure and heavy dependence on the imported fossil fuels; (2) heavier environmental load caused by rapid industrialization and urbanization; (3) global climate change; and (4) the necessity for new growth engines. In their review Korea was commended for taking an active role in formulating and implementing the new concept of the "green growth" national vision.

Compared to the worldwide total, the Korean GHG emissions are more concentrated in the energy transformation and industry sectors. The two sectors account for the 29.9% and 37.2% of the national GHG emission, while equivalent world averages are 25.9% and 17.4% respectively (PGCC 2009; McKeown and Gardner 2009). Electricity generation by coal and energy- and the carbon-intensive industry structure are responsible for this. The Korean energy input per unit GDP is among the highest in OECD countries. This figure alone imposes a huge challenge for the green growth strategy of Korea. The national energy strategy and industrial strategies should be redesigned to address this problem.

The Korean response was swift and comprehensive. The overarching national strategy and 5 year action plan came from the PCGG, whose members were recruited from the governmental ministries and the private sector. A full variety of area strategies and plans followed to support the PCGG plan.

2.1.2 Green Growth Strategy: The Contents

The national green growth strategy sets the direction of green growth as follows: (1) the virtuous circle of environmental sustainability and the economic prosperity; (2) the green revolution of improving the quality of life; and (3) the global leadership of Korea in the green growth area.

The 5 year action plan states the three strategies and ten policy directions as follows:

Measures for climate change and securing energy independence

1. Reduce carbon emissions
2. Decrease energy dependence on oil and enhance energy self-sufficiency
3. Support adaptation to climate change impacts

Creation of new growth engines

4. Develop green technologies as future growth engines
5. Greening of industry
6. Develop cutting-edge industries
7. Set up policy infrastructure for green growth

Improving quality of life and the status of the country

8. Green city and green transport
9. Green revolution in lifestyle
10. Enhance national status as a global leader in green growth

The plan has many quantitative goals, including a 107.4 trillion won fiscal investment plan and the expected economic effects of 182–206 trillion won. It also states that Korea will become “World Green Power” No. 7 by 2020 and No. 5 by 2050. This is a typical Korean governmental plan. Even though its apparent goal is to pursue qualitative growth, departing from initiatives based on the quantitative growth of the past (UNEP 2009), the plan still lists many numbers according to a couple of scenarios.

In preparing the 5 year action plan, all governmental ministries have worked on more detailed area plans to support it. In this chapter we will review the 5 year plan itself and the three most important constituent area plans, (1) the national energy plan; (2) the green growth industry strategy, and (3) the green technology R&D policy.

2.2 Review and Analysis

Low-carbon green growth has become imperative for all nations as they face climate change, energy and resource depletion, and stagnating economic growth. This challenge, however, is no trivial matter. The implications encompass everything from technological innovations in most industries to radical changes in lifestyle and social order. In order to pursue the deep and wide innovation of this magnitude, the national innovation systems should exploit the market and non-market institutions and mechanisms. Dynamic interaction of competition-based incentives, collaboration, and cooperation on the network of private firms and public institutions is crucial. From this viewpoint we review the Korean LCGG plan and the supporting area strategies and plans.

2.2.1 Vision, Goals, and Philosophy

The stated vision of the 5 year plan is for Korea to become a “World Green Power.” The three strategies and ten policy directions clearly reflect the philosophy of pursuing the competitive advantage of the nation. The associated 50 action plans are also compatible with this direction. Based on the newly established national low-carbon infrastructure, Korea wants to secure the energy and resource supplies, and protect itself from environmental disasters and climate change. At the same time the plan makes it clear that there will be huge new markets in the world for Korean firms to explore. Public-private cooperation for green technology innovation is supposed to help the Korean economy to grow in this new market.

“The national energy plan 2008–2030” of the National Energy Committee (2008) also explains the 2030 energy vision: (1) a self-reliant energy supply; (2) low energy consumption and low-carbon society; (3) less-dependence on oil; (4) an energy-equitable society. In summary, it pursues more overseas gas and oil exploration (40% of imports), increases new and renewable energies to 11%, and reduces

47% of the energy demand by reducing consumption and increasing efficiency. The notable addition in this plan is the appreciation of the universal energy service for the poor. The Korean Energy Act of 2006 states that it is the responsibility of the central and local governments and energy suppliers to provide the basic energy needs for all people. According to this mandate, the plan estimates that 7.8% of Korean households are "the energy poor," who spend more than 10% of household income for heating and lighting. The plan sets the goal of eradicating energy poverty by the year 2016.

This plan, however, faced opposition, mainly for its heavy reliance on nuclear energy and less ambitious goals for demand reduction and the new and renewable energy sources. Civil society demanded more aggressive demand reduction goals and heavier investments into new energy sources. There seem to be a conflict of interest between the energy intensive industries and civil society.

The Ministry of Knowledge Economy (2008) published the "industrial strategy for green growth," where the vision of "green transformation of Korean industries" is explained. It elaborates on green innovation (GI) in nine major industries, the six green restructuring (GR) initiatives, and the six green value chain (GV) initiatives. They call this "the 3G 9-6-6 strategy." The nine major industries include steel, petro-chemical, textile and fashion, automotive, shipbuilding, machinery, semiconductor, display, and digital appliances. The GI strategies address the technological challenges to operating in the new business environments of a low-carbon society and the governmental strategies to help businesses to strengthen their competitiveness. The GR and GV initiatives are mainly governmental policy measures to upgrade the business infrastructure, focusing on areas such as incubating the knowledge-based service industry, intellectual property strategy, and green IT and logistics.

The National Science and Technology Council (2009) also published "green technology R&D policy toward 2020," whose stated vision is "to build green power through green technology." In this plan three major goals are measured in numbers: (1) the national green technology competence to be 90% of the world best level; (2) green industrial competence with 160,000 green tech jobs by 2012, and a world green market share of 10% by 2020; (3) environmental sustainability index world ranking 10th by 2020. They chose 27 key technologies on which to focus, and provide the technology development strategy based on convergence ideas. The council suggested that Korea should exploit its strength in advanced industrial technologies, and combine them with bio-, information, and nano technologies to develop new green technologies. The governments will double green R&D investments by 2012 and focus more on basic technology, where commercial development of new green technologies will be led by a collaborative business network. The 27 key technologies are classified into five categories: (1) climate change forecasting; (2) energy input; (3) high process efficiency; (4) end-of-pipe or by-product treatment; and (5) knowledge-based cultural technology.

Reviewing the LCGG strategy and its constituent area plans, it is clear that they are quite comprehensive and aggressive. The vision they share is for Korea to become one of the leading nations in the LCGG world, and they pursue this goal by exploiting their existing industrial strengths, and catching up and upgrading to

Table 2.1 The Korean national strategy formulation

Name	Legal basis	Principal agency	Planning horizon
Green Growth Strategy and Action Plan	Framework act on low-carbon green growth	Presidential Committee on Green Growth	Strategy: 2050 plan: 2013
National Energy Plan	Energy act	National Energy Committee	2030
Industrial Strategy for Green Growth	Government organization act	Ministry of Knowledge Economy	Unspecified
Green Technology R&D Policy toward 2020	Framework act on science and technology	National Science and Technology Council	2020

overcome any technological weaknesses. The philosophy behind this aggressive plan is not new. Korea has always been preoccupied with ranking orders in the world. The LCGG trend has given the country a new sense of direction and goals to pursue at any cost. The plans do not seriously contemplate what is really necessary for human civilization to get closer to sustainability. They just take the new trend as a change in the business environment to which a new elaborate strategy should be formulated. This lack of philosophical change will have serious impacts on the integrity of the strategy, acceptability, and the attainability of the visions and goals, which we will examine later.

2.2.2 Process and the Participants

Korea is well known for its success in government-driven economic development. Behind this success, there always were long-range plans. The 5 year plan inherited this tradition and infrastructure. It even states that they consciously tried to revive the old “Korean success model” for green growth. Table 2.1 summarizes the four major plans analyzed in this chapter, which clearly shows how the governmental policy making processes work in Korea.

In terms of major policy areas like green growth, energy, or national R&D, the Korean government has “framework acts” that dictate the policy-making and implementation processes. The presidential committees or major ministry responsible for the policy appoint a special task force, which almost always includes leading academic experts, researchers, professionals from businesses, representatives of civil activists, and government officials. As most of these experts have worked together in similar task forces on many occasions, their cooperation is usually quite smooth. The diversity of task force participants is the reason why all these plans are so comprehensive. But at the same time, the inclusion of diverse interest groups inevitably results in compromises and a lack of focus. The plans usually have something for everybody. The coordination of the task forces are usually done by government officials, who are responsible for the final approval of the draft plans by the committees or the ministry.

The Korean policy formulation processes are well-established and successful in producing ambitious and comprehensive plans and strategies. But the implementation is another matter. Compared to the old governmental plans and policies, the national strategies today usually include big contributions from the private sector. To private businesses, these national strategies are just reference materials, and the government has no power to enforce them. Even governmental spending in these plans has no guarantee of realization, for governmental budgets are decided by the National Assembly. Considering the processes and inherent uncertainties of these strategies and plans, the specific goals of numbers and rankings become less credible.

2.2.3 Contents and Integrity

In any strategic plans, the major focus should be the elaboration of what to do, how to do it, and why. The why part of the Korean LCGG strategy is clear. Climate change and the need for a new growth engine are the two apparent driving forces of the plan. The decisions made by the Korean government are also clear. They announced the goals of GHG reduction and green transformations of industries. The question is whether the rest of the strategic plans are good enough for the goals.

In order to examine the question, we borrow a benchmark from a Japanese study (NIES et al. 2008). The coverage and aggregation level of this study is comparable to that of the Korean PCGG strategy, but a stark contrast is apparent in the organization of the vision and action plans. The Japanese goal is 70% CO2 emission reduction by 2050 below the 1990 level. They developed two different scenarios for society in 2050 and a dozen action areas, which contribute differently to the ultimate goal according to the scenarios. Scenario A, called "Vivid" assumes that technological breakthrough in clean energy and energy efficiency areas can help Japan keep up a comfortable and convenient lifestyle, and achieve the highest economic growth possible. Scenario B, called "Slow," however, assumes an entirely different future, where a decentralized community-based lifestyle will prevail. In spite of the different assumptions, they conclude that the 70% reduction goal is attainable through the dozen action items. The contribution of each action to the reduction goal is elaborated under the two scenarios. It is notable that they explicitly considered the interactions among measures in different sectors in estimating the GHG reduction contributions. In sum, the Japanese study connects the goal and actions with explicit number estimates of reduction contributions. If somebody disagrees with the report's conclusion, then they can analyze and criticize the specific assumptions, estimation process, as well as the final numbers.

In contrast, the Korean PCGG has never revealed the composition of their GHG reduction goal, a 30% reduction of the BAU forecast of 2020 (Dong-A Ilbo 2009). Without this information, it is very difficult to evaluate the plan in terms of whether it is possible to attain the goal. We conclude that this is why there have not been any serious debates or strong resistance among stakeholders in Korea. It is also speculated that industries oppose any strong reduction targets, and the burden may be transferred to residential, commercial, and transportation areas. If this is the case, then the future socio-economic changes of Korean society will be huge. In the plan, however, there are no detailed descriptions or alternatives for these social changes.

Although the Korean green growth strategy and plans received a quite favourable review by UNEP (2009, 2010), there are similar weaknesses in other areas too. The growth part of the strategy states that there will be new jobs, big new markets, and improvements in the quality of life. But there are no detailed explanations of how these results can be attained by the list of actions in the plan. In another example, both the PCGG strategy and 5 year action plan briefly mention the joining of the Marrakech Process, which is designed to support the elaboration of a 10-Year Framework of Programs on sustainable consumption and production (SCP), as called for by the WSSD Johannesburg Plan of Action (UNDESA and UNEP 2010). If the Korean government were serious about SCP, then its LCGG strategy and plan should have elaborated in terms of how they would incorporate the principles and ideas of SCP. Unfortunately no explanations could be found in either document. The lack of integrity can be a serious barrier for the effective communications and education of citizens, which are also included in the action plan.

2.2.4 Policy Tools and Implementation

Since a national strategy of this magnitude cannot be implemented without strong support and participation from the private sector, the policy measures adopted in the plans are aiming at the collaborative participation of citizens and businesses. The 5 year plan explains the five policy measures as follows: (1) governmental investments; (2) new regulations; (3) an incentive mechanism using tax and subsidies; (4) internalization of externality using market mechanisms like emissions trading; and (5) moral persuasion. They strongly argue that utilizing market mechanisms can be more efficient than traditional regulations.

The governmental investments are directed mostly to the basic research, human resource development, national platform projects, and upgrading the national innovation infrastructure. The Korean government has rich experiences in these areas, and the overarching PCGG plays a crucial role in coordinating the multi-ministry efforts. It is well known in Korea that there is serious competition among governmental agencies trying to increase their influence in important policy areas. In the environmental policy area, the Ministry of the Environment and the Ministry of Knowledge Economy have a long history of conflicts, which often resulted in duplicate investments and conflicting regulations and support policies. Recently there was a strong criticism from industry against the duplicate carbon emission monitoring regulations. Stronger coordination and clear division of labour is necessary in this aspect.

Introducing more stringent regulations to control the carbon emission is inevitable. The market mechanism of emissions trading depends on the "cap and trade" principle. The plans are not particularly clear in this area. How best to share the cost of emission reductions and industrial restructuring should be proposed and open to a debate in order to reach a national consensus. The lack of a detailed allocation of burden can also be a huge obstacle against the "moral persuasion" policy measures.

2.2.5 Stakeholder Approval

Since most governmental strategies and plans are prepared by task forces composed of many stakeholders, different viewpoints and opinions can be integrated in the final drafts. This practice is quite efficient and usually works well. However, there are three potential problems associated with this practice. First, as there are many stakeholders participating in the process, the final plan can be a result of compromises. This is why many action plans in this area contain long lists of action items. The green frenzy of the Korean public sector in recent years seems to have let everybody come up with green growth projects. The resulting lack of focus can be unsatisfactory for many stakeholders. Second, no matter how hard a task force tries to incorporate diverse interests in the plan, it is impossible to satisfy everybody. In the Korean green growth policy area, the voice of strong environmentalism, anti-nuclear groups, and conservative scepticism about climate change have not been heard seriously. Also there are controversies on the issues involving "the four river restoration project" and heavy dependence of nuclear energy. Many environmentalists and foreign observers insist that the planned increase of new and renewable energy sources is too small. These weaknesses of the PCGG strategy and plans may be partly responsible for some harsher critics branding it "green washing."

Big businesses seem to agree on the general directions of the national green growth strategy. Leading business groups have announced their long-term investment plans in the green growth areas. Other public institutions in higher education and research areas are also working together with governmental agencies. This can be seen as one of the strengths of Korean society. In contrast to these big players' understanding and participation, small and medium enterprises (SME's) and local governments are not well represented in the planning process. Traditionally this has not been a serious problem in Korea. But in present-day, democratized Korea, resolutions of conflicts of interests have become much more difficult than before. When more detailed implementation plan and policy measures are revealed, there can be serious resistance from the stakeholders who were not sufficiently represented in the planning process.

Finally, the biggest stakeholder of all, the general public of Korean society, is not well informed about the national green growth strategies. This is partly because the detailed contents are not fully open yet and also because the policy-making processes are practically closed to the general public. Before marketing and education, there must be more open public debates on the crucial issues discussed so far.

2.2.6 Global Implications of the Korean LCGG Strategy

Korea has been taken as an exemplar country that has accomplished both economic development and democratization. These days Korea has one of the most open economies in the world, and many Korean businesses play an important role in the globalized supply chains. Under the Korean LCGG strategy, big businesses are implicitly assumed to be leaders in technological innovations and industrial restructuring. There are already some success stories in this area. LG Chemical and Samsung SDI have become the world leaders in the large-scale battery production that is crucial to the success of hybrid and electric vehicles. Hyundai Motor Company is well known for its fuel-efficient cars and the recent success of introducing new hybrid cars. POSCO, one of the best steel makers in the world, recently started the commercial operation of the FINEX iron making process. This innovative technology is expected to reduce CO_2 emission by 44% (after CO_2 sequestration) compared to the conventional blast furnace technology. All of these world-class Korean companies do business globally, and thus their innovations can have a positive impact on the world-wide efforts to reduce carbon footprints.

Another possible contribution of the Korean LCGG initiative to the world may come from the Smart Grid Test-Bed project on Jeju Island that began in 2009 (KSGI 2010). This project is currently known as the largest smart grid community project in the world. The test-bed project will help test advanced technologies, business models, and stakeholder impacts. Smart grid is a strategic infrastructure in which information and communication technologies (ICT) are integrated to the existing electric power system and real-time information exchange on the grid becomes possible. Through its adaptation, energy conservation, new and renewable energy distribution, and penetration of electric vehicles is made possible. In 2009, Korea was named the leading nation for smart grids along with Italy at the G8 Extended Summit. Other countries joined this initiative to share the experience. The state of Illinois, USA with Argonne National Laboratory and Chicago University agreed to join the project. They announced that they would apply the Jeju test-bed results to Seoul and Chicago later on. The technological, business and social innovations learned from this initiative can be duplicated worldwide.

There can be negative impacts of Korean LCGG efforts to the world too. There have been strong arguments, especially from developing countries, that rich industrialized countries have exported the polluting industries to the poor regions of the world. In this respect, Korea finds itself in the middle of the argument. It is a fact that Korea imported some of these “dirty” industries from rich countries in the past. If the Korean GHG reduction goals are allocated to industries and more stringent regulations are enforced, then it is possible for some small GHG-intensive companies to flee to countries with weaker regulation and enforcement. It is our opinion, however, that this cannot be a serious problem for two reasons. First, from the long experience of global climate change negotiations, there cannot be many countries that would import the "dirty" industries without proper compensation. Second, many SME's in Korea are either entirely domestic, or closely connected to the supply chains of globalized companies. Global big businesses are becoming responsible for the life-cycle GHG emissions of their products. So small companies either cannot leave the country, or must reduce their GHG emissions wherever they go as long as they want to stay in business with the big players. By the same token, we conclude that enforcing stringent regulations and scrutinizing the global supply chain leaders' life-cycle GHG emission performance are most important from the global perspective.

2.3 New Framework for LCGG Strategy

2.3.1 Dynamic Interaction Perspective

The Korean LCGG strategy was well accepted by international organizations and the media. They are comprehensive and ambitious in pursuing the new path of qualitative growth. As we appreciate the merits of the strategy and plans, there is also room for improvement. As we discussed in the previous section, the plans are relatively static in terms of their philosophies and policy measures. The green transformation of Korean industry cannot be successful without corresponding changes in the socio-cultural value system. Also the list of action items and technology innovations are open to complex and dynamic interactions among players in both domestic and global markets.

In Fig. 2.1, we outline the suggested policy-making framework. Climate change and international pressures to reduce the carbon emission can be huge threats to the Korean economy and society, but at the same time there also can be many opportunities for Korean industries to explore. This point is well covered in the current Korean LCGG strategy. We propose that all the analyses, planning and evaluation should be measured in terms of national carbon footprints. This information is not readily available now, so the 5 year plan emphasizes the development of a national carbon visibility index and carbon disclosure project. More comprehensive national carbon accounting can be useful in setting strategic goals and implementing the plans.

The next point in Fig. 2.1 is that the economic and environmental consequences of policy measures are determined by complex interactions in markets. Not all the technological innovations or industrial transformation efforts survive market competition. Also the market itself can change following shifts in the underlying value systems of the society. This aspect is not well addressed in the Korean LCGG

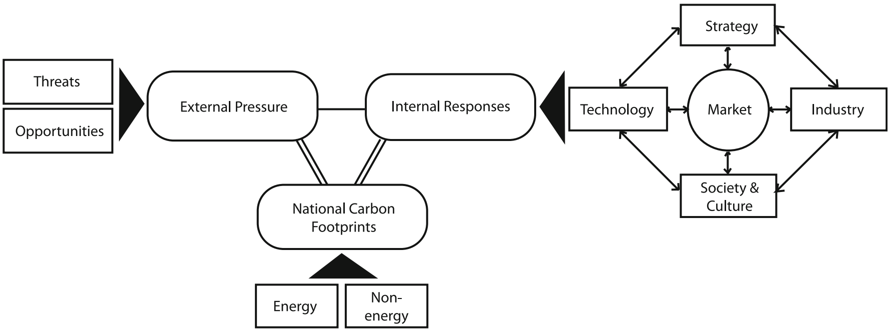
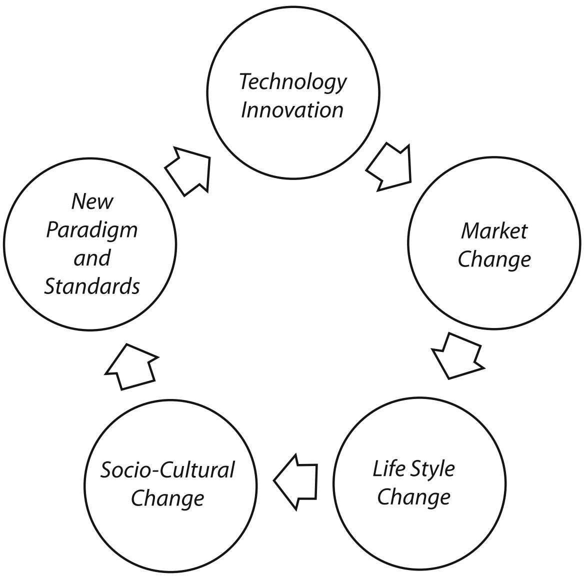


Fig. 2.1 New framework for the LCGG national strategies

Fig. 2.2 The dynamic interaction of social change



strategy. Even the Japanese study of (NIES et al. 2008) does not fully cover the complex dynamics of these interactions. Another important point implied in the right-hand side of Fig. 2.1 is that the national strategy and policy measures (top-down) mainly interact with technological innovations and industrial responses. As we examined above, national LCGG initiatives can only try indirect measures in terms of the social and cultural change dimensions, such as education and communications. Socio-cultural changes are not open to direct control by nature, but their influences (bottom-up) are much more profound and long-lasting. From this observation, we propose that the policy-makers should pay more attention to the interaction along the lower triangle, that is, technology innovation, industrial responses, and socio-cultural value changes. A simple way of exploring the phenomenon is depicted in Fig. 2.2.

Since the planning horizon of the LCGG strategy is from 10 to 40 years, it is imperative to take into account of the long-term structural changes in markets and cultural values. The existing simple scenario planning approaches are not good enough for this purpose. We stipulate that more elaborate simulation models are necessary in this area.

2.3.2 Global Supply Chain Perspective for Sustainable Consumption and Production

In today's globalized economy, no single nation can hope to accomplish its national LCGG visions and goals entirely within its borders. American electric vehicles sold by GM are equipped with batteries manufactured by LG Chemical in Korea, which depend on the Lithium supply from Bolivia. Similarly, Starbucks sources its coffee beans from mostly developing countries, and T-shirts sold in Wal-Mart are made in China using cotton harvested in India. The key point here is that in most supply chains today, the businesses from developed countries are closely linked to raw material supplies from developing or underdeveloped countries. Big brand names are facing ever-increasing scrutiny from various stakeholders on their social and environmental performance along their supply chains. Coffee and Farmer Equity (C.A.F.E.) practices of Starbucks or the sustainability strategy of Wal-Mart are well-known corporate responses to the challenges. Policy makers should adopt similar approaches to better contribute to the global cause of SCP. While rich countries try to reduce the consumption for their LCGG purposes, about two thirds of the seven billion people on earth live under the poverty level. In order for the SCP vision to be realized, restructuring of global supply chains in many industries is imperative.

For this purpose, sporadic efforts from big businesses are not enough. National LCGG strategies should fully consider the global impacts and consequences of their policy measures. The Clean Development Mechanism (CDM) adopted in the Kyoto Protocol can be a benchmark to develop evaluation criteria for LCGG policy alternatives. This also can be a good safety measure to prevent so-called pollution export practices. Underdeveloped countries need to develop the economic and social infrastructure to support their people's sustainable consumption and production. They need all the help they can get. Korea is in a unique position in this area. Thanks to its rapid economic growth out of poverty, Korea still has the experts who remember the early stages of its economic development. The knowledge and skills of these veterans include economic and social policy, education, healthcare, agriculture, construction, light industry, and so on. They experienced development from the most primitive levels of the national infrastructure to the most advanced levels, so many of their skills can be quite useful in underdeveloped countries. This is not the case in most other industrialized countries. If Korea wants to contribute to the global community with its LCGG strategy, then it should incorporate the global supply chain perspective to support SCP.

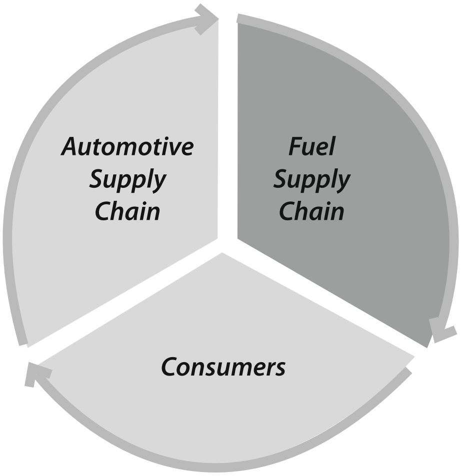


Fig. 2.3 Platform competition

2.3.3 Platform Competition

The LCGG strategies heavily rely on technological innovations in many areas. The complex dynamics of new platform technology competition make it very difficult to choose the best alternative among many competing platforms. It is well known that many platform competitions can be modelled as a two-sided market (Eisenmann et al. 2006). In two-sided markets, the nonlinear network dynamics make analyses very difficult. In the Korean national LCGG strategy there are many technology platforms to be analyzed in this context. The best-known example is low-emission vehicle technology. There are many competing technology platforms such as high efficiency internal combustion engines, hybrid electric vehicles, plug-in hybrid, full electric vehicles, and fuel-cell electric vehicles. Many countries and industry leaders are struggling to figure out how to make their strategic choices facing these many alternatives. The most interesting feature of this competition is that there are three distinct sides in this market as depicted in Fig. 2.3. The new vehicle technology platform should exploit the positive network externalities in this market. Electric vehicles need the electricity charging stations or battery exchange stations, as well as new players in their parts supply chain involving efficient battery and motor suppliers. Similarly, fuel cell electric vehicles need the hydrogen supply chain to be acceptable by consumers. The national strategic choice among technology options should consider this network dynamics.

Any one nation or one big company can never explore all these possible platforms and develop the necessary supply chains. Also it would be nearly impossible to reach a global agreement for one preferred platform because there are so many stakeholders in these areas. When formulating the national LCGG strategies, we propose the evaluation of the economic and environmental performance of alternative platforms and their network externalities.

2.4 Summary and Conclusion

From the critical reviews of all the relevant governmental and private responses to the challenge of LCGG, the prominent characteristics of the contents and processes of the Korean national strategy are summarized as follows: (1) Korea has long and successful experience in public and private cooperation in policy issues during its economic development era, the lessons and the infrastructure which was fully exploited in developing the green growth strategy. The intensive catch-up efforts were the main reason for the fast completion of planning. (2) Most plans include ambitious goals and cover all relevant areas and well-known alternatives. Everything was carefully examined from world rankings, market potentials and employment potentials. (3) In spite of the apparent comprehensiveness of the green growth strategy, however, the integrity of the constituent plans was not assessed kindly by civil society. Some activist groups even criticized the strategy as a "green wash." This shows that the core groups of people with various backgrounds working in the endeavour have not sufficiently considered the diverse views and opinions of all stakeholders. (4) The strategy also seems to have some other weaknesses. It lacks the qualitative vision of life in low-carbon society, in-depth dynamic analyses of the changing world, and the credibility of the ambitious goals and numbers. All these weaknesses should be addressed in the subsequent elaboration during the implementation of the strategy.

The results from this case study enable us to propose a new framework for development and evaluation of national low-carbon, green growth strategies. We emphasize the interaction between external pressures and the internal responses, based on the national carbon footprint. Internal responses are the results of another dynamic interaction among the political leadership and policy measures, diverse sets of technologies, and industries under social and cultural contexts of the nation. In addition to this, even a nation's LCGG strategies should consider the global impact of their policy measures along the global supply chains. We focus on various stakeholders who can compete against and cooperate with other players in the game. Low-carbon, green growth strategies need many disruptive changes in business and technology platforms. There are huge uncertainties in the competition among alternative platforms. We propose a multi-sided market competition model to help analyze the dynamics of this phenomenon. The evolutionary progress toward a global standard will decide the performances of these efforts.

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Chapter 3
Greening the Korean Stacks Through Lessons from the EU Emissions Trading System: A Socio-legal Analysis

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Abstract A reduction of the greenhouse gases emissions is one of the most important policies to tackle the long-term changes to the climate system. The emission trading schemes are flexible market mechanisms, which, if implemented wisely, can contribute to achieving sustainable green growth. The chapter will, firstly, review the relevant literature indicating the theoretical underpinnings and the crucial elements of an effective emission trading system. Secondly, it will analyse the legal framework of the European Union Emission Trading System and assess its achievements and challenges. Thereafter it will trace the legislative and institutional development of the Korean counterpart which is in the development stage. In its conclusion the chapter will suggest policy alterations which Korean government could implement to increase the efficiency of its scheme. It will argue that the Korean government should centralise the governance of its scheme to increase market liquidity and reduce a threat of favouritism. Moreover, Korea should contribute to developing effective mechanisms to combat carbon leakage and establish links with other similar schemes at the global scene.

Keywords Effective emission trading • Comparative study • European Union • Korea • Green growth

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3.1 Introduction

Green growth requires an integrated strategy at the national and international level which, if successfully implemented, will lead to environmentally sustainable growth. The addressees of the green policies include a range of small and medium enterprises (SMEs) as well as the large businesses as other papers in this book illustrate. Accumulation of efforts and/or resistances to greener pathways of development will have an impact on climate change, which forms the critical part of the OECD strategy. The reduction of the greenhouse gases (GhG) emission became one of the most important policies to tackle the long-term changes to the climate system. Thus, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997, hereafter Kyoto Protocol) obliged the most polluting Parties listed in the Annex 1 to cut, "individually or jointly", emissions "by at least 5% below 1990 levels in the commitment period 2008–2012" (Article 3, Kyoto Protocol). The emission trading mechanism, entrenched in the Article 17, was set to supplement "domestic actions for the purpose of meeting quantified emission limitation and reduction commitments". This flexible, market-based mechanism is widely acknowledged to have been inspired by the US pollution permit schemes (Banks 2000; Damro and Mendez 2003). Yet, before and during the Kyoto negotiations, it encountered strong resistance and opposition from the European Union. The latter saw loopholes in the US-based flexible trading mechanisms and proposed more rigid framework including "binding targets and fixed timetables" (Damro and Mendez 2003:84). Towards the end of the negotiations the EU moderated its position and accepted certain elements of the flexible trading mechanism whereas the US was unable to proceed with the Protocol's implementation due to the insufficient number of participating developing countries. This led to the EU's taking the leading role on the global environmental arena (Sbragia and Damro 1999).

Today, the EU Emission Trading System (hereafter EU-ETS) is the largest emission trading scheme in the world, both in terms of trade volume as well as in its geographical scope. It is often referred as a leading carbon market since it has already progressed from its pilot phase, from 2005 to 2007, and has begun its second phase in 2008. As a result it provides an excellent benchmark for analysing emerging trading schemes beyond the EU. In this chapter we focus on drawing lessons from the EU scheme to inform the developing and dynamic South Korean Emission Trading mechanism (hereafter SK-ETS). It is a fascinating study because Korea, at the time of the Kyoto negotiations, declared itself as a developing country and was not included in the Annex I countries. Given the growing pressure building in the international circles the country committed itself to developing an ETS. It is also an important analysis because the Kyoto summit negotiations illustrated how the initially opposed policy was later incorporated into and dominated the EU environmental strategy. The success of the climate change mitigation will depend on the collaboration of all global actors and, currently, particular attention is being refocused beyond the US and Europe (Zakaria 2011). Major infrastructure projects are located in the 'Post-American World' including Korea, and there is a need to conduct the comparisons between Asia and Europe (Kheng-Lian et al. 2009).

Below we offer the methodological note as the study is based upon some empirical work. Thereafter we offer a brief review of the relevant literature indicating the theoretical underpinnings and the crucial elements of any emission trading system. In the third part we will review institutional and operational frameworks of the EU ETS in secondary market and assess the achievements and challenges of the scheme. Thereafter we will trace legislative and institutional development in SK-ETS. In conclusion we will suggest policy alterations which Korean government could implement to increase the efficiency of the scheme.

3.2 Methodology

Initially we reviewed literature in economics and law with a number of official papers in order to understand the crucial principles and elements of an effective emission trading. In particular, we focused on Garnaut Climate Change Review (2008) which provides useful theoretical suggestions. Further, we analysed the EU-ETS legal framework at different stages of development. We paid a particular attention to the original Directive 2003/87/EC (First EU-ETS Directive) and the amending legislation, namely Directive 2008/101/EC (Second Amending Directive) and Directive 2009/29/EC (Third Amending Directive). We also analysed the Consolidated Directive 2003/87/EC which will provide the regulatory basis for the Phase III of the EU-ETS. Due to the limited space and the different status of the EU and Korea we excluded the Directive 2004/101/EC (First Amending Directive), which regulates the linkages between the EU-ETS and the Kyoto Protocol. Given the relative immaturity of the Korean scheme we looked at the Low Carbon Green Growth Act 2010 to understand the foundations of the pilot scheme. Further, our analysis of the achievements and challenges of the EU scheme and the lessons to be learned by Korean government were underpinned by the available statistical data and interviews. We performed the latter at the beginning of 2011 with three emission trading specialists in each country through snowballing (Goodman 1961).

3.3 The Effective Emission Trading Scheme

Leung et al. (2009) summarises the major advantages and drawbacks of emission trading as illustrated in Table 3.1. Alongside the economic and environmental benefits, emission trading is capable of "turning pollution prevention from a 'burden' into a 'business'" (Lee 2005). Yet it can become bogged down in political arguments and be very expensive in the initial stage.

There are critical features that need to be addressed in the development stage of emissions trading schemes since the emission market (or carbon market) differs substantially from a traditional commodity market. Given the adverse effect of GhG on climate it is imperative to decrease the current levels of emissions. These efforts benefit the environment, thus it is in the public interest to develop a

Table 3.1 Advantages and disadvantages of emission trading

Advantages	Disadvantages
Cost efficient: cheaper than other reduction methods.	Controversial: some allege that trading pollution is unethical and put poorer countries at disadvantage.
Flexible: Reduced barriers to entry and exit. Limited bureaucratic controls.	Untested: experiences in emission trading are limited mainly to the developed countries.
Environmentally sound: since the total emissions will be capped by the regulatory agency.	Political Barriers: many political obstacles to implant an emission trading scheme especially when they involve cross-border participation.
Growth potential: provide growth for new business and trading opportunities.	High start-up costs: It is expensive to set up a comprehensive permit trading system that is practical, effective and easy to operate.
Economically viable: business could make profit through permit trading.	Long set-up time: lengthy discussion among different participants, particularly those cross border, may delay the time for emission reduction.

Source: Adapted from Leung et al. (2009)

cap and trading scheme and to oblige certain actors to participate. The supply of emission allowances must therefore be limited and decrease over time. The principles and critical elements that should underpin effective emissions trading are considered below.

Garnaut's Climate Change Review suggests five principles, namely: scarcity, credibility, simplicity, tradability, and integration (Garnaut 2008). Firstly "[m]arket participants must have confidence that permits are in scarce supply and reflect the targets and trajectories for national emissions reductions" (Garnaut 2008:323). Uncertainty over scarcity of permit allowances leads to a fluctuation of price. Secondly, any changes in the policy can have an adverse effect on participants' confidence. Thus, "steady and transparent operating rules are a necessary condition for the credibility of the market" (Garnaut 2008:323). Thirdly, the rules should be simple and easily explicable to ensure easy implementation and the participants' understanding. Complicated rules increase uncertainty in the market and increase the transaction costs for market participants. Thereafter tradability is critical to enhance the market functionality of the emissions trading scheme. It requires a clear definition of a permit, benefits of transactions, trade mechanism, and terms and conditions of trade. By assuring tradability, emissions trading will encourage the accessibility to market for potential participants and assist in improving operational efficiency and transparency. Lastly, emission trading must be integrated into other financial, commodity and product markets at domestic and international level. This principle requires free dissemination of information within and between markets. In addition, the polluter-pays-principle is critical in the process of improving the environmental performance of the economy. In essence, polluters should pay for pollution prevention and control measures, as well as for environmental damage caused, while the government should not subsidise polluting activity (Woerdman et al. 2008).

The OECD (2002) suggests that allocation modes, system coverage, banking and borrowing provisions, incentives and enforcement systems are the major design elements of an emissions trading scheme. We focus on the wider list of elementary features as suggested by Garnaut (2008) below.

Cap setting and commitment period: In the cap setting and commitment period, the total amount of emissions allowed within certain time period is set.

Coverage: the scope of the sectors, the gases, and regions (or country in case of international emission trading scheme) must be set; the core consideration is the selection of the GhG emissions.

Permit: the emissions cap for the scheme will be divided into equal permits which enable the holder to emit a certain quantity of greenhouse gas; for simplicity different gases are comparable when they are translated into carbon dioxide equivalent (CO_2-e); entities that kept their emission below the level of their allowances can sell their excess allowances at a price determined by supply and demand at that time; those facing difficulty in remaining within their allowance limit can take measures to reduce their emissions or buy extra allowances.

Allocation mode: this has a distributional effect by distinguishing winners and losers among participants (Egenhofer 2007); there are three allocation methodologies, which are benchmarking, grandfathering and auctioning; under benchmarking standard allocation is made based on the best practice; grandfathering amounts to free distribution and auctioning meets the polluters-pays-principle by selling permit to the participants through auction.

Banking and borrowing: banking allows the use of unused permits in the future while borrowing allows use of permits from the future. Inclusion of banking and borrowing in an emissions trading scheme could contribute to stabilising the allowance price and increasing certainty in carbon market.

Linkage with other emission trading schemes: national emission trading schemes have limited market size but require a certain amount of capital to establish the system; even though linking with another emission trading scheme may bring negative impacts such as loss of control, compatibility and possibility of linking with other emission trading schemes, it should still be considered in the design stage; thorough cost-benefit analysis is required to prepare for the further expansion of the emission trading scheme at international level; we will not consider this aspect below due to limited space.

Penalties: for those who do not comply with rules and who do not meet an emission reduction target, emission trading scheme should include provision of penalties.

3.4 Framework of the EU ETS

The EU ETS is designed as a cost-effective instrument to achieve the European Union's emission reduction target (Article 1, Harmonised EU-ETS Directive) and has been implemented in stages. Phase I, a trial period for the EU ETS began on 1 January, 2005 and was completed on 31 December, 2007. Phase II is running from 2008 and will end in 2012 which coincides with the Kyoto Protocol's compliance period and goals. Phase III will run from 2013 to 2020 and, independently from post 2012 negotiation outcome, will aim at a reduction target of 20% below 1990 level. Major institutional elements for the EU ETS such as coverage, cap, allocation method, trading units differ at various stages.

During the first and second periods of EU ETS the emission cap was set by each Member State(MS) through National Allocation Plans (NAPs). NAP detailed the total quantity of European Union Allowances (EUAs) to be allocated for given trading period with a portion reserved for new entrants. MSs must have developed its NAP in compliance with objective, rules, and criteria listed in Annex III to the EU ETS Directive. NAPs must have been published and notified to the European Commission no later than by 31 March 2004 for Phase I, or 18 months prior to the onset of Phase II. The European Commission reviewed the plans and decided on their approval. NAPs detailed the total quantity of European Union Allowance (EUA) to be allocated for given trading period, with a portion of EUAs reserved for new entrants, the amount of EUAs to be allocated for each covered installation, allocation method, and percentage of Kyoto credits allowed. Thus, the sum of the emission cap of each MS amounts to the overall EU ETS emissions cap as agreed between the EU MSs and the European Commission. Meanwhile, 5% of this single EU-wide cap will be set aside for new installations for those who wish to enter the EU ETS post-2012.

As to coverage, initially EU ETS covered CO_2 emission from large installations in 15 MSs of the EU. The covered sectors included the iron and steel, cement and lime, refineries, pulp and paper, ceramics, glass, bricks and tile sectors during first and second phase (First EU-ETS Directive). Under Article 27 a temporary provision providing for an exclusion of certain installations (Opt-out Rule) expired on 31 December, 2007. As of 2008 EU MSs were allowed to cover additional activities, installations, and greenhouse gases. The Second Amending Directive included the aviation industry and the Third Amending Directive included other sectors which will be covered in the third phase. The EU step-by-step approach was subject to litigation, reviewed briefly below.

In terms of permits, the EU ETS Directive regulates activities listed in Annex I to the EU ETS Directive and GhGlisted in Annex II. Thus, each covered installation requires a permit to emit greenhouse gases. The GhGpermits are issued by public authorities in the EU MSs and cannot be traded unlike the EUAs. Each EUA is equivalent to 1 tonne of CO_2 and is valid for emissions during the trading period. Installations which emit beyond their allocated emissions cap can offset these excessive amounts by purchasing an equivalent amount of EUAs.

Further, in the first two stages free allocation dominated the distribution of allowances:

> For the three-year period beginning 1 January 2005 MSs shall allocate at least 95% of the allowances free of charge. For the five-year period beginning 1 January 2008, MSs shall allocate at least 90% of the allowances free of charge (Article 10, Directive 2003/87/EC)

From 2013 auctioning will dominate the distribution. The power sector and carbon capture and storage (CCS) installations will be subjected to full auctioning with effect from 2013. Other sectors will be subjected to 20% of auctioning in that year, gradually increasing year-on-year to 70% in 2020 and 100% by 2027. Up to 50% of revenue from auctioning should be spent on GhG emissions reduction, renewable energy, energy efficiency, CCS, forestry, public transactions, or adaptation (Article 10(3) Harmonised EU-ETS Directive).

Banking and borrowing of EUAs is allowed within each trading period. Inter-period banking was initially allowed for EU MSs but temporarily prohibited by most of them due to problems with over-supply of EUAs in the first trading period.

As to penalties, by 30 April each year, operators are required to surrender sufficient allowances to cover their reportable emissions made in the previous year. Operators failing to comply with this "shall be held liable for the payment of an excess emissions penalty" imposed by the appropriate regulator in each country (Article 16 EU-ETS Directive). The penalty is calculated as the amount in tonnes of carbon dioxide equivalent by which the annual reportable emissions exceeded the allowance, multiplied by €100.

3.5 Achievements and Challenges of the EU ETS

There are two main questions[1] relevant to the analysis of the EU ETS performance: whether it has achieved its environmental goal (i.e. emissions abatement), and whether it has worked as a market instrument. We will successively analyse each question:

3.5.1 Has the EU-ETS Achieved Its Environmental Goal?

The performance of the EU ETS in terms of emissions abatement was successful to some extent (Grubb et al. 2009; Convery 2008). Ellerman and Buchner (2008) estimated that the EU ETS has reduced European emissions by 120–300 million tonnes of carbon dioxide ($MtCO_2$) during its first trading period. They also indicate that during its first 2 years the EU ETS resulted in a small absolute decline in emissions instead of the estimated 1–2% annual increase projected in the absence of the scheme.

In 2010[2] the European Environment Agency reported a significant 11.3% drop in emissions from 1990 to 2008 levels. Indeed, the Agency indicated that the EU-15's

[1] Other questions can relate, for example, to the achievement of social objectives of the EU ETS (see for example the Article 17 of the Harmonised EU-ETS Directive).

[2] 'Annual European Community GhG inventory 1990–2008 and inventory report 2010'.

emission levels in 2008 were even 6.9% less than the target aimed by the EU's Kyoto Protocol base year level. Yet, we are reluctant to accept that the drop in the emissions occurred solely due to the EU-ETS. More comprehensive studies are needed to include other factors such as technological innovation and the recession which resulted in the economy's slow-down. Thus, the success of the EU-ETS cannot be assumed only on the basis of a drop in emissions.

3.5.2 Has the EU-ETS Worked as a Market Instrument?

The answer to this question is more complex and we first need to outline the main financial mechanisms of emission trade markets. In financial terms, emissions trading creates dual market structures, divided into the primary cash market and the secondary market. The former refers to the initial distribution of allowances by government while the latter refers to the marketplace where allowances are traded (Pew Center 2010:3). Hedges (2009:324) depicts the market for emission trading in Europe through an analysis of two types of trades and two market segments. The *forms of trade* are spot transactions and forward transactions, the *segments of the market* are Over-The-Counter (OTC) markets and the exchange markets.

Spot contracts are for a specified quantity of allowances where delivery will occur immediately or within short period of time after the transaction is agreed (Hedges 2009). This is similar to the physical exchanges of traditional commodities such as oil, metal, or corn. Spot trades occur physically between two parties, a buyer and a seller "on the spot".

Forward transactions concern a specified quantity of allowances where delivery and payment will occur at certain point of time in the future. Such a transaction occurring in OTC market is called 'forward' and in an exchange market called 'future'. The delivery date for forward in OTC market is 1 December of each calendar year while a futures contract is not fixed but generally falls around December. Forward transactions are the main trading instruments in the EUA market.

Under the EU ETS installations must surrender allowances equal to their emissions by the end of April in the following year. Thus, installations which emit more than their cap need to purchase EUAs to cover the excess quantity of emissions. Moreover, installations which wish to hedge exposure to risk from current production can either purchase the required EUAs in the spot market or purchase a futures contract corresponding to the compliance year for which allowances will be surrendered (Ellerman and Joskow 2008).

1. Over-the counter markets (OTC) refers to transactions which are negotiated between two parties either directly or via the broker (Hedges 2009). The OTC market uses less standardised contracts with less regulatory oversight. Thus, it is characterised by higher risk than the exchange market. In contrast to OTC markets, the exchange markets involves a number of regulated electronic

trading platforms with standardised contracts determined by the exchange (Hedges 2009). The transaction at risk is relatively lower than the OTC market since exchange ensures that the non-performance by one party to a contract will not affect the other party via a clearing house.

Thus, coming back to the second question, the success of the EU ETS as a market instrument depends on trading volume, the existence of single price, and the development of efficient trading platforms (Hedges 2009).

An increasing trading volume suggests the market has liquidity which is essential for market functionality. The trading volume of the EU ETS has grown steadily since 2005. In the first quarter of 2005, the average trading volume per month amounted to about 10 million EUAs and it grew to around 50 million in the first quarter of 2009 (Ellerman and Joskow 2008). In terms of volume of CO_2 emissions traded, transactions peaked at around 700 Mt CO_2e in December 2009, then going down to 500 MT CO_2e 1 year later (EEA 2010). These figures suggest that, despite fluctuations, there is enough liquidity to grant market functionality.

A visible single price for a given product is the pre-requisite for an efficient market for a homogeneous product without transportation costs (Ellerman and Joskow 2008). In emission trading based on cap-and-trade system a single price informs the market participants that marginal cost can be economically compensated by reducing emissions and adjusting production processes. A key indicator to assess the success of EU-ETS as market instruments is the existence of single price and trading volume of future contracts for delivery in 2007–2008 (phase 1) and 2008–2009 (Phase 2).

In terms of single price, the first outcomes of EU-ETS were disappointing. Given the unavailability of banking in Phase I, the prices of the future contract for delivery in December 2009 and December 2007 started to diverge after following the release of verified emission data in April 2006. In December 2006, the price for future delivery in 2007 collapsed from 30 million EU/tonne to around 5 million EU/tonne (EEA 2010). However from 2007 onwards, once restrictions on banking and borrowing were lifted in the Phase II, the emergence of a single price of future contacts for delivery in 2008 and 2009 is noticeable (EEA 2010).

In terms of trade platforms, most EU ETS transactions have occurred on the riskier over-the counter market. However, trading volume in exchanges has been growing steadily since 2005, when a number of exchanges opened in Leipzig, London, Paris, and Vienna. Each exchange trades different instruments currently, more than one-third of all trades take place on exchanges. (Pew Center 2010:5). Below we identify the most important ones:

2. The European Climate Exchange (ECX), which opened April 2005, is now by far the largest single platform for trading future contracts. ECX offers futures, options, swaps and other derivatives. As a subsidiary of the Chicago Climate Exchange (CCX) of the US, it traded 380million tons of CO_2 equivalent in 2007 accounting for about 87% of exchange volume (Yang 2009:56).

3. The Nord Pool was originally a power exchange and now it also trades EUAs and Certified Emission Reductions (CERs).[3] As of 2008, 124 installations were participating in the Nord Pool and it accounted for the second largest trading volume under the EU ETS.
4. The European Energy Exchange (EEX) is trading spot and futures. Its trading volume of futures has rapidly increased from 300 million EUAs in 2006 to 18 billion in 2007. The EEX uses Xetra the Germany stock trading system.
5. The Bluenext, based in Paris, started out offering spot and future contract of EUAs and CERs.
6. The NYME located in New York is the largest commodity exchange in the world. Since it began trading in EUAs in 17 March 2008, it offers CERs as well. It is the only exchange offering EUAs transaction outside Europe and also allows the transactions for pre-compliance and transactions for voluntary markets

As we saw above, there is no clear-cut answer to the question whether the EU ETS has met its fundamental goal of GhG emissions reduction. Yet, it is clear that there are foundations for building a solid market for EUAs exchange. These achievements must be set against the background of a number of shortcomings which emerged during the two initial phases. Next, we will analyse these issues by reference to the following shortfalls: the over-allocation of permit allowances; the price volatility of EUAs; windfall profits to the power sector; prevailing concern over carbon leakage among participants; allowance theft and litigation.

Over-allocation occurred when the MSs created excessive number of allowances during the trial period (Ellerman and Joskow 2008). The over-allocation increased the price volatility and led to uncertainty on the market. Indeed, as we mentioned before, the price of EUAs plunged following the release of verified emission data in April 2006.

Member States decided upon cap-setting and allocation methods during first and second phase of the EU ETS. Egenhofer (2007) argues that a combination of decentralised rules and modest caps based on inflated projections resulted in the plunge. Moreover, differences in energy mixes and intra-EU development contributed to this situation. Each MS used different criteria to establish NAPs primarily in their favour. Their emission cuts were set modestly, somewhere between ‘less than the business usual’ and ‘a path consistent with the Kyoto Protocol’. Moreover, a lack of information on emissions allowed MSs to heavily rely on government projection for cap-setting. The problem was that government projections were inflated given the positive economic climate. Thus, many MSs expected that emissions would climb in the future with robust economic activities (Egenhofer 2007). A combination of these factors created a surplus of almost 5% of total annual allowances (Kettner et al. 2007) with the price reaching almost 0 in May 2006.

One of our UK interviewees argued that, in Phase III:

> allocation is going to be more harmonised and based on fixed output benchmarks, which is the most efficient way to provide free allocation [...] greater auctioning would provide greater efficiency (Interview Transcript)

[3] See the Article 12 of the Kyoto Protocol.

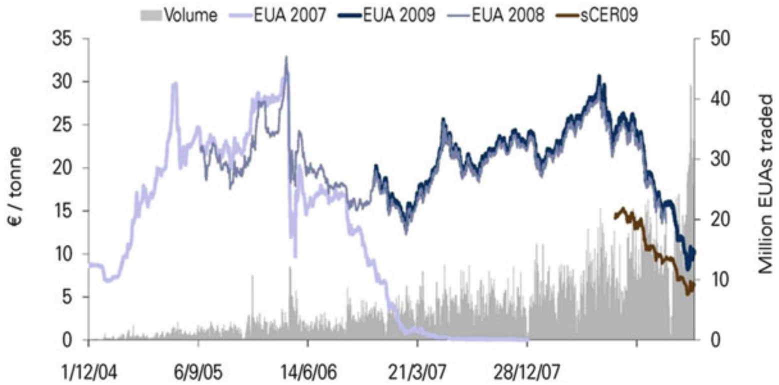

Fig. 3.1 EUA prices and volumes 2004–2009 (Source: Point Carbon, Carbon 2009, page 5, 17 March 2009)

Moreover, in our opinion, it is critical to ensure reliable information on emissions, the existence of centralised rules and progress for cap-setting and allocation, and tighter cap setting. Our analysis shows that the EU-ETS, in its initial stage, did not satisfy the major principles of the effective emission trading, namely scarcity, credibility and simplicity (compare with Garnault 2008 above).

Secondly, price fluctuation (clearly visible at Fig. 3.1) was caused by the failure in the supply-demand control due to over-allocation; lack of information on the market; and other factors such as weather conditions and high fuel prices. Interestingly, the lack of information until the first emission data disclosure in April 2006 resulted in participants' conviction that allowances were in shortage. This belief contributed to price upsurge in the first few months. Moreover, freezing and a long winters in early 2005 followed by a dry summer in southern Europe contributed to the price upsurge. These factors combined with high natural gas and oil prices at that time creating greater demand for coal and effectively for EUAs (Ellerman and Joskow 2008).

One of our UK interviewees highlighted lack of long term certainty:

> While the EU ETS is now sure to be around until 2020, there is uncertainty beyond that timeframe and still some discussion about changing the cap to aim for a deeper cut by 2020. This level of uncertainty is difficult for the market to deal with (Interview Transcript)

It follows that the issue of price volatility is also associated with a breach of the Garnault's principles. Furthermore, the inclusion of flexible provisions for banking and borrowing would help to reduce uncertainty in the market.

3.5.2.1 Windfall Profits and Free Allocation

Unfair profit made by passing the cost of free allowance onto consumers in the energy prices ("windfall profits") emerged during Phase I and II. The overall question of whether energy producers have benefited unfairly from the introduction of the EU ETS is contentious. The increase in energy pricing after the free allocation of allowances gave rise to a valid concern that producers have reaped huge profits. The UK Ministry of Trade and Industry estimated that UK utilities made additional profits of around €1.76 billion in 2005 (Point Carbon 2007). Overall annual windfall profits in 2005–2006 were between €24 and 35 billion (Sijm et al. 2006).

Windfall profits are in obvious and serious breach of the polluter-pays principle reviewed above. The power sectors escaped the burden of the cap and it might be possible that other sectors had to pay an additional price (Grubb and Sato 2009). Woerdman et al. (2008) highlights that it is only auctioning that is consistent with the polluter-pays principle because it internalises pollution costs and forces polluters to purchase their allowances. The EU acknowledged the problem and revised allocation rules to increase the portion of auctioning in its third phase starting in 2013.

However, since auctioning is controversial in its impact on the competitiveness of certain industries, it requires more research. Furthermore, new allocation rules introduced in the EU include a provision of exemption from auctioning for certain sectors which are regarded to be exposed to the risk of carbon leakage through newly adopted risk assessment methodology. Thus, to avoid windfall profits strong governance is required to increase the level of enforcement with the scheme as well as developing a new policy instrument that can address this issue.

3.5.2.2 Carbon Leakage

The term ‘carbon leakage’ is defined as the increase in emissions outside the region as a direct result of the policy to cap emission within the region. The occurrence of carbon leakage means that domestic mitigation policy is less effective and more costly in containing emission levels (IEA 2008:2). Clò (2010) insists that auctioning will increase the risk of carbon leakage since the more stringent emission cap in the third period is imposes a unilateral, asymmetric and costly emission reduction burden on the installations included in the scheme. He also points out that the newly introduced risk assessment methodology in the amended EU Directive is arbitrary and insufficiently economically grounded in determining which sectors will be at the risk of carbon leakage. Since it threatens both the environmental effectiveness of the market and the socio-economic status of countries that lose part of their industrial activities, it is critical to find alternative ways to cope with this issue (UN Global Compact 2009). Alternative approaches may mitigate the leakage such as border adjustments and a carbon tax for imported goods from heavy emitting countries. However, additional research is needed to find the optimum solutions.

3.5.2.3 Allowance Theft

The EU Commission halted spot emission trading on 19 January 2011 for 3 weeks when EUAs were stolen from carbon registries in the Czech Republic and Austria. This suspension was the longest disruption in EU ETS history. A total of 1.3 million permits were missing from six Czech accounts and the digital assets were transferred to accounts in Poland, Italy, Estonia, and Germany and possibly other countries. Energy consultancy Point Carbon estimated the value of spot trades lost during the market closure at more than €100 million. Exchanges reopened in early February 2011, but trading volumes remained very low, because of traders' concerns over the status of stolen EUAs. The suspension of the spot market has not prevented trading on the futures market, which usually accounts for 80% of total trading activity. However, trading in futures was at about half the normal level when the suspension was imposed. Despite the Commission's proposal of enhanced security measures in 2010, 14 of the 30 EU ETS registries did not take all the recommended security measures. To prevent future fraud the EU Commission plans to apply a delay to the transfer of EUAs between registry accounts and may limit transfers per day or per transaction. It may also stop displaying permits' serial numbers to registry account holders and market players when it introduces a single registry from 2013.

3.5.2.4 Litigation[4]

The EU-ETS scheme can be challenged by operators and MSs by way of judicial review in the European General Court (EGC) and the Court of Justice of the European Union (CoJ). Moreover, certain aspects of the scheme can be the subject to domestic litigation, which can ultimately reach the EU courts.[5] Phase I and Phase II have generated a considerable amount of litigation, where, firstly, MSs challenged the overall lawfulness of the EU-ETS, secondly, the MSs challenged the EU Commission's powers to review the NAPs; and, thirdly, the operators whose activities are covered by the EU-ETS challenged EU decisions concerning NAPs (Maurici 2009). The cases in the third category failed due to the lack of *locus standi*, thus, we will review examples[6] in the first two categories.

Firstly, the steel producing *Société Arcelor Atlantique et Lorraine* (SAAeL 2008) challenged French law which transposed the EU-ETS Directive into the domestic legal system. One of their arguments concerned an alleged breach of the principle of equality to the effect that the producers of non-ferrous metals and chemicals, not covered by EU-ETS, would gain competitive advantage while

[4] We decided not to describe the procedural matters concerning litigation in the EU as it would consume much space in this chapter. We are convinced that it is not necessary as our aim is limited to noting that litigation can expose legal and political problems and, in turn, inhibit or threaten the development of the emission trading.

[5] The domestic litigation, in which a question over the interpretation and validity of the EU acts is raised, can be referred by way of preliminary ruling to the CoJ (Article 267 of the Treaty on the Functioning of the European Union).

[6] We reviewed only two examples however there have been a large number (around a 100) of challenges to the EU-ETS.

likewise emitting considerable amount of greenhouse gases. The CoJ agreed that the steel sector and non-ferrous metals and chemicals sector (producing plastic and aluminium for example) were in comparable position and treated differently. Thus, the different treatment could only be objectively justified with some degree of discretion, which should be carefully exercised. In the present case the objective justification concerned the protection of the environment and the discretion, disfavouring SAAeL, concerned the need to launch the EU-ETS. This discretion allows the Commission to take a step-by-step approach in achieving the objectives sought by the EU-ETS, summarised as:

> a novel and complex scheme whose implementation and functioning could have been disturbed by the involvement of too great a number of participants, and, second, that the original definition of the scope of the directive was dictated by the objective of attaining the critical mass of participants necessary for the scheme to be set up (SAAeL 2008 at 60)

Secondly, there were a number of challenges to the NAPs including *Republic of Poland v. Commission* (Polish case 2009), which raised the issue of differences in Community development as a legal argument. Poland allocated the cap on emissions amounting to 285 million tonnes CO_2 equivalent in its NAP in 2006 for the Phase II EU-ETS. The NAP was rejected by the Commission on procedural grounds and Poland was allocated a smaller allowance of 208.5 million tonnes of CO_2 equivalent. Poland challenged the Commission in the EGC, which annulled the latter's decision. The carbon market noted a drop in price of the EUAs following the judgment (Bodoni and Stearns 2009) thus injecting uncertainty into the market. Yet, on the other hand, the case exposed the economic and political differences in the largest emission trading market. Less developed countries, such as Poland, might not be expected to meet the stringent EU emission targets. Poland argues that its efforts to meet emission targets led to a high 20% unemployment in the country (Polish Ministry of Environment 2010).

3.6 Korean Emission Trading System

Since 1990, GhG emissions in Korea have increased rapidly, due to the growth of energy intensive industries and relatively stabilised international oil price. Between 1990 and 2007 total GhG emission increased by 103% from 314.6 million tCO_2 to 620 million tCO_2 with annual increase rate of 6.1% (Korea energy Economics Institute 2005). The country is the 9th largest CO_2 emitter in the world and 6th largest among OECD member countries (IEA 2009). In this context, the implementation of climate change policies to mitigate GhG emission is critical. Given the internal and external pressures, the Korean government announced a voluntary emission reduction target on 17 November 2009. Its ambitious target is 4% reduction based on the 2005 emission level of Korea or a 30% reduction based on the business as usual (BAU) estimation by 2020.

Even though this target is voluntary the Korean government launched a pilot emission trading programme as of January 2010 (Low Carbon Green Growth Act). It encountered strong opposition from industrial groups, which insisted that the scheme would weaken the competitiveness of major export industries including carbon intensive industries, such as the automobile, ship building, steel, and petrochemical industries (Lee 2009). However one of our Korean interviewees insisted that the industrial groups had weak arguments. The root cause of their opposition lies in the anxiety that the emission trading scheme under the Ministry of Environment would impose greater burden than the GHG emissions management scheme under the Ministry of Knowledge Economy does.

The initial construction of the scheme was also hampered by conflicts inside the Korean government. Our Korean interviewees noticed that there were political power games between Ministry of Environment and Ministry of Knowledge Economy concerning a question of who should take the control over emissions trading scheme.

As of 13 January 2010, the Low Carbon Green Growth Act aims at creating the foundations for environmentally sound economic development, and encouraging green technologies and green industries as part of a new growth momentum to create low carbon green growth society. Article 46 introduced an emission trading scheme in Korea. It also provides a legal ground for linkage with other international emission trading schemes in Article 46 Clause 2. In addition, in Clause 3, it states that relevant legal action can be taken if installations weaken the international competitiveness of Korean by emitting excessive GHG in relation to its emission reduction cap. However, as Article 46 Clause 3 states, allocation method, registry, management method, establishment and operation of exchange will be set by other legislation. Thus, much must be done to develop further legislation for these critical areas.

The Government announced the implementation of a pilot emission trading scheme in January 2010. Following a consultation phase with the relevant stakeholders the pilot emission trading programme was officially launched. The Ministry of Environment took the overall control over the operation of the programme.

This scheme is divided into two different systems depending on the scheme participants. The first one is for what we broadly categorise as *big corporate emitters*,[7] and the second one covers *local governments*. In turn the pilot for big corporate emitters involves two types of participants: type 1 business operators (business with operations that emit over 80 millions tons of atmospheric pollutants annually) and large-scale buildings (large retailers' stores). These two systems are based on the same framework but also have distinctive features. Since critical parts

[7] There is no official translation available for this pilot program. The term 'big corporate emitters' used here to describe the participants in the first system is not a direct translation of the Korean term used in the pilot program: "sayupjang". Sayupjang loosely translate as "operations" and refers to recurring activities involved in the running of a business for the purpose of producing value for stakeholders.

of pilot programme are still under development and a detailed plan is not yet released to the public, this research provides the major features of these two systems decided so far.

3.6.1 Trading Period

The Pilot emission trading programme will run from 2010 to 2012. Operational schedules are different depending on the category of participants. For private companies the operational schedule begins from January of each year by starting the assessment of actual emissions of each participant. Then, based on data and required documents submitted by participants, the operating body will approve emission permit allowances for each participant. Trading of emission allowances is available from June 2011. In turn, Local governments' operational schedule begins from March 31 of the each trading year. The verification process was done during May and emission trading is available from June 2010.

3.6.2 Cap-Setting

The pilot programme has distinctive cap-setting methodology which depends on the type of participants. The operators and large scale building caps will be set based on average emission of 3 years from 2005 to 2007. The emission reduction target is 1% from based on 3 year average. For local government, the emissions reduction target is 2% based on the emissions over 2 years from 2007 to 2008.

3.6.3 Coverage

Unlike the EU ETS focus on specific industrial sectors, the pilot emissions trading programme in Korea categorises its participants into three groups, namely type one business operators, large scale retailer's stores and local government. Examples of type one business operators participating are Samsung Electronics, Samsung Electro mechanics and Dongbu Steel. The retailers involved are three: E-mart participating with 60 stores, Homeplus also with 60 stores; and Lotte-mart, second largest Korean retailer (49 stores) As of now, 30 type one business operators, 169 large retailers, and 501 government agencies under 14 local government departments are all participating in the pilot emission trading programme. It is therefore necessary to include a larger number of industry operators. It is also necessary to include other emitters (i.e. cattle farms, transport industry). Initially, the scheme covers CO_2 and will be expanded to other green house gas emissions. However, the covered CO_2 is restricted to emissions from energy producers and vehicles.

3.6.4 Permits and Trading Units

Each participant requires a permit to emit CO_2, which is issued by a public authority in Korea. Each participant should report their monitoring plan to the operating body for approval. Once participants obtain approval, they assess the actual emissions they discharged. Then, actual emission data is verified by a verification entity (third party). After that participants should reassess their emission for more accurate data. The verification process will thereafter be repeated.

The Korean allowance unit (KAU) is a ‘property right’ which can be traded. Each KAU is the equivalent of a right to emit 1 tonne of CO_2 and is valid for emissions during the trading period.

3.6.5 Allocation Method

The allocation method for corporate emitters is still under development. At this stage local government departments should allocate, free of charge, permit allowances to the participants quarterly and annually. They can however modify detailed allocation rules for each participant in the given area. This can lead to the existence of divergent rules and favouritism similar to that observed in the EU-ETS.

3.6.6 Banking and Borrowing

Banking is permitted for corporate emitters but it is not yet known whether borrowing will be allowed. For local governments, banking is allowed and borrowing is forbidden according to the Article 17(2) of Operational Rules of Pilot Emission Trading for Local Governments by Ministry of Environment.

3.6.7 Penalties

Unlike the mandatory EU ETS the Korean pilot scheme created a voluntary market. Korean government and local government offer participating entities technical and financial support in order to increase participation under the Article 19 of Operational Rules of the Pilot Emission Trading for Local Government. Nevertheless, the installations that do not surrender enough allowances to cover their emissions in the previous year have to obtain additional allowances to make up the shortfall in the following year, and must pay a fine for each excess tonne of CO_2. Moreover, such participants have restricted access to government incentives, such as subsidies, and to the permit allowances in the following year.

3.7 Analysis and Conclusion

It is not clear whether the EU ETS contributed to reducing greenhouse emissions but it certainly faced challenges that weakened the efficiency of the scheme such as over-allocation of allowances; high volatility in EUAs price; windfall profits of power sector; rising concern over carbon leakage and allowance theft. These inter-linked challenges were derived from a combination of design flaws in the institutional framework of the EU ETS and subsequent response from the allowance market. Moreover, a number of exogenous factors played a role in creating these challenges. Based on this analysis this research suggests a clear relationship between critical features of institutional framework of the emission trading and its overall efficiency.

Firstly, critical features of the institutional framework of emissions trading such as cap-setting and allocation directly affect the secondary market for emissions trading by virtue of price fluctuations. Secondly, volatility in price caused by modest cap-setting and subsequent over-allocation decreases the certainty and credibility of the market (in combination with other exogenous factors such as fuel price and weather conditions). Thirdly, design flaws such as free allocation (grandfathering) have had an adverse effect on the economy, the environment and society by creating issue of windfall profits. Fourthly, stringent compliance for tight cap and auctioning might affect the economy and the environment. The covered industries might shift their operation outside of the EU region since increased cost for emission allowances and abatement activities might weaken their competitiveness in the international market. Fifthly, however, the issue of carbon leakage cannot be solved by changing the design features since they are closely linked to the overall efficiency of emission trading. Thus, other approaches are required to resolve this issue. Our research indicates the following lessons learned from the EU ETS based on the above analysis and the interviews

- Lesson 1: for accurate cap-setting, high quality emission data is required.
- Lesson 2: centralised cap-setting with unified rules and procedures is required to maintain the consistency and predictability of the scheme.
- Lesson 3: centralised allocation processes and rules are required to avoid favouritism for certain industries by MSs due to national priorities for economic development.
- Lesson 4: strong governance is required for enforcement of auctioning together with the development of complementary policy instruments to avoid windfall profits.
- Lesson 5: banking is required to keep the flexibility and long-term certainty in the market.
- Lesson 6: the selection of participant installations must consider the contribution of installations to GhG emissions. For instance, small installations account for 36% of total installations whereas they are only responsible for 0.7% of emissions. Meanwhile large emitters that account for 7.5% of total installations are responsible for 60% of emissions.

- Lesson 7: complimentary policy measures are required to address the issue of windfall profits and carbon leakage outside of emission trading scheme.
- Lesson 8: complementary regulation is required for oversight of the secondary markets of emission trading to avoid manipulation of price.
- Lesson 9: reinforcements of the security of the electronic transactions and monitoring of the registry system is required to prevent fraud and crime.

Finally, suggestions will be provided an institutional framework design stage based on lessons learned from the EU ETS.

Firstly, the Korean market is voluntary but we expect that emission trading will become compulsory in the near future. Yet the lack of clarity as to the future direction of the market can cause concerns over credibility and affect the international recognition of the allowances. Secondly, the SK-ETS can become too complex given the focus on the types of actors rather than sectors, as in the EU. The Korean approach could create divergent rules and processes for each group especially due to a large discretion enjoyed by the local governments. Thus, it could bring the potential problem of double accounting of the emission and dual standard for participants which emit similar amounts of greenhouse gases. It also could bring modest cap-setting and favouritism for certain sectors in permit allowances allocation. Finally, the limited geographical reach of the Korean scheme could create problems of liquidity in the emission market. To avoid these challenges and to develop efficient emission trading scheme in Korea we propose the following solutions.

Solution 1: Centralised allocation processes and rules are required to provide consistency and predictability in the market; such rules are in line with the principles of simplicity and credibility

Solution 2: Korea should link with other similar schemes in Asia; however, bearing in mind the issue of litigation in the EU and the Polish case, Korea should link with states at the similar level of development

Solution 3: Korea should develop Internationally Transferable Permit Allowance to ensure market liquidity

Solution 4: Korea should develop Complementary Policy Measures for Carbon Leakage; the country should work with other states in achieving this goal

3.8 Conclusion

In this chapter we have offered a succinct review of the relevant literature indicating the principles and crucial elements of an effective emission trading system. We have emphasised five principles of scarcity, credibility, simplicity, tradability and integration found in the Garnaut Review (2008). Later we reviewed institutional and operational frameworks of the EU-ETS in the secondary markets and assessed the achievements and challenges of the scheme. It is difficult to ascertain whether the EU-ETS achieved its environmental goal but it is certain that it laid the foundations for a secondary market. However, the process was long, costly and resulted in numerous market disturbances and much litigation. Thereafter we traced the legislative and institutional development of the pilot SK-ETS. It became clear that the current decentralisation could create challenges such as these encountered in Europe. Furthermore, we noted, through interviews with our respondents, conflicts in the Korean government over the scheme's leadership and industries' opposition to emission trading. These might generate the threat of litigation above the future developments of the scheme unless the current conflicts are resolved through mediation and consultation. All in all, emission trading schemes, if properly implemented, may contribute to sustainable green growth in a longer term. As the European case illustrates, the establishment of the scheme can be extremely costly and produce no tangible green development at the initial stage. We hope that Korea will wisely avoid these problems.

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Chapter 4
Sustainability Science Integrated Policies Promoting Interaction-Based Building Design Concept as a Climate Change Adaptation Strategy for Singapore and Beyond

Harn Wei Kua and Sylvia Koh

Abstract The latest IPCC report reinforced the idea that a complete climate change strategy must consider both the mitigation and adaptation aspects of addressing the causes and possible effects of climate change. The Singapore National Climate Change Strategy (NCCS) has included both these strategic aspects. Although the NCCS contains broad directions and statements on adaptation, there is almost no mention in the industry at the national level on the detailed strategies to adapt building stocks and infrastructures to cope with the possible consequences of climate change. This study sets out to find out what local industry experts think the most likely effects of climate change in Singapore are, and the most suitable strategies of adapting building stocks and infrastructures to these likely effects. A series of structured interviews were conducted using the Delphi technique. Incoherence was observed between the arrived consensus on the possible effects of climate change on Singapore and the required strategies. Based on this observation, an integrated interaction-based design concept for building was proposed by first characterizing the problem with three design elements – water, soil and built environment. Various policy strategies were then suggested, which were then combined with the help of four integrated policy strategies aimed at promoting adaptation measures for the building industry. Suggestions were also given on how this model can also be applied to countries and territories at large.

Keywords Integrated policymaking • Climate change adaptation • Construction industry • Delphi study • Singapore

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4.1 Singapore's Green Growth Aspirations and Its Concerns of Climate Change

Singapore has established itself as one of the most industrially vibrant countries in the world today. With the vision to balance the various aspects of development, in 1992, it established its first Green Plan, which is a master plan for environmental projects, aiming to transform the island nation into a healthy green city by the year 2000. In 2002, the new Singapore Green Plan 2012 was unveiled; it is a 10-year national blueprint to build a sustainable environment with an update every 3 years. This has since led to the review of some of the original plans and targets in 2006. Between 2006 and 2010, a few important milestones were established. Foremost was the formation of the Inter-ministerial Committee on Sustainable Development in January 2008. The Singapore Sustainable Blueprint contains the strategies and initiatives that are believed to enable Singapore to achieve both economic growth and a sustainable living environment over the next two decades. The Sustainable Blueprint focuses on a few key issues, including improving resource efficiency, enhancing its environmental quality, building up a knowledge foundation and database to address sustainability issues, and encouraging community ownership and participation in building a clean, green and resource efficient country.

Climate change strategies did not officially enter Singapore's policymaking agenda until the Singapore National Climate Change Strategy (NCCS) was released in February 2008. The NCCS is basically comprised of two overarching dimensions – the mitigation and vulnerability/adaptation strategies. The main thrusts of the mitigation actions lie in increasing the energy efficiency of Singaporean industries, especially the power generation, manufacturing and construction industries. In the building industry, more specific design requirements have also been introduced on various fronts. For example, the Building Control Authority (BCA) has established the minimum energy efficiency standards under the Building Control Regulation, under which all air-conditioned buildings must be designed such that the Envelope Thermal Transfer Value (ETTV) is less than 50 W/m^2. In order to encourage best practices, the BCA also introduced the BCA Green Mark Scheme (GMS) in January 2005. The scheme is intended to raise awareness among various parties in the construction industry and to promote sustainability in the built environment. Under this scheme, a scoring system is used to evaluate buildings for their environmental performance and impacts. While a detailed review of the many laws and non-regulatory measures that are meant to mitigate climate change is beyond the immediate scope of this work, it is evident that, as a whole, Singapore's adaptation efforts are less developed and defined.

Being an island nation, Singapore's growing concerns over the effects climate change will have on its economy and social well-being is one of the driving forces that prompted it to action, resulting in the formation of these recent policy initiatives. Some of the likely outcomes due to climate change have been widely discussed, especially in dialogue sessions and town hall meetings involving the governmental and non-governmental sectors. Coastal land loss, for instance, is a major concern. A projected rise in sea level of up to 59 cm, in the worst case scenario, is expected to cause parts of Singapore's coastal area to be submerged. More specifically, there are evidence that increased coastal erosion has already started to affect the East Coast Park, a hugely popular stretch of beaches and recreational areas along the eastern coast of Singapore (Cheam 2009). In view of rising sea levels and more regular occurrence of heavy downpours resulting in flash floods, Singapore also plans to reduce flood prone area from 124 ha in 2006 to less than 66 ha in 2011. This is believed to ameliorate inland flooding or storm surges at the shoreline caused by strong winds blowing inward from the sea. In fact, recent flash floods in Singapore further exposed the inadequacies in the present nationwide drainage systems and road infrastructure during irregular heavy downpours.

On the other hand, rising global average temperatures may result in changes in rainfall patterns resulting in a net reduction of rainfall during certain periods of time. This will reduce the overall amount of water captured and stored in reservoirs – a source of serious concern for the already water-strapped country (Kua and Gunawansa 2009). Finally, heavy downpours may result in possible spikes in cases of dengue fever, which is caused by the creation of puddles of stagnant water in which Aedes mosquitoes can breed; although this has proven to be relatively easy to tackle in built-up areas throughout the island, the problems are harder to address in the suburban regions, especially the areas in the south west part of Singapore.

Unlike mitigation strategies, the local construction industry does not have a set of well-developed and tested ideas for adapting existing building stocks and infrastructures and future stocks to deal with the possible consequences of climate change. Put in another way, the national level visions on adaptation articulated within the NCCS have not yet been translated into detailed strategies that can be readily executed from the macroscopic urban design level to the microscopic building level. If these steps are missing from the "operational wisdom" of the local construction industry, the grand statements outlined in the NCCS can never be useful. It is this need for greater specificity that defines the three key objectives of this work, which are: (1) to identify the likely adverse effects of climate change on the building stocks and infrastructures in Singapore; (2) to identify the main design and technological approaches to tackle these adverse effects; (3) propose integrated design and policy strategies to address the identified problems, and any discrepancy between the problems and proposed solutions.

4.1.1 Theoretical Context: Sustainability Science and the Need for Integration

Between 1988 and 2002, our understanding of the need for sustainable development has seen several important milestones. In particular, a study by the United States National Academy of Sciences, Our Common Journey (National Research Council 1999), argues that policy development must be supported by science-derived knowledge that is gleaned through a rigorous process of hypothesizing, observation, measurement, interpretation, verification and dissemination. This study sets the stage for emergence of the field known as sustainability science. Sustainability science can be summarized as a field that generates knowledge on the complex interactions between natural and social systems and their roles in affecting Earth's sustainability. Kates et al. (2001) proposed a framework for generating useful knowledge to support a transition to sustainable development. This framework not only seeks to illuminate the relationship between the natural and social systems, it also aims to develop methodologies to guide and monitor the outcome of actions taken in the social system on the natural system.

Four sustainability science research strategies were proposed; they are: (1) spanning multiple spatial scales from local to global processes; (2) accounting for temporal inertia and urgency of problems that are aim to generate knowledge usable for people with different perspectives. In their proposal to adopt scenario analysis as a tool for sustainability science, Swart et al. (2004) identified an additional concern not addressed by Kates – how can the future be scanned in a creative, rigorous and policy-relevant manner that reflects the normative character of sustainability and incorporates different perspectives? Their key point is that scanning of likely future scenarios of development must be preceded by an effective mechanism of engaging a multitude of stakeholders to generate those scenarios. They went on to propose five research strategies – all of which can be summarized by four pillar concepts. These pillar concepts can be described with the following four adjectives:

Integrative

This means that effective sustainability solutions to observed problems should consider the economic, environmental and social factors that contribute to the problem – across all appropriate spatial and temporal scales, applying an integrated approach comprising of qualitative and quantitative methodologies. It also means that effective solutions are the result of integrating the views from a wide range of relevant stakeholders (Kua 2007).

Participatory

To be able to integrate the views of different stakeholders, the process of policymaking must be participatory in nature. The key to stakeholder participation is creating a stewardship toward the desired outcomes of the strategies.

Reflective

An individual's capacity to contribute to sustainability solutions depends on whether he/she has the opportunity and is willing to make the necessary behavioural or ideological changes necessary for the contributions to occur – a point also highlighted by Kua and Ashford (2004). The preamble for the willingness to change usually involves a self-reflection on the impacts one's actions have on the larger nature-society system.

Place-based

To increase the success of policy solutions, problem identification and solution formulation must be carried out by those who are familiar with the problems in question. Stakeholders who can identify themselves with the problems in question are also more likely to be willing to participate in formulating solutions.

In short, these four adjectives collectively describe the nature of a policy strategy that is designed in a "sustainability scientific" way. Case studies conducted on policy strategies promoting sustainability in the building material sector – namely, concrete aggregates in Sweden and Denmark, wood in Chile and the United States, and alternate fuels for cement production in the United States and United Kingdom – revealed that one of the reasons behind the occurrence of unintended, negative consequences of policies is that these policies are conceived in a fragmented manner (Kua 2007, 2011). In particular, when policymakers neglect certain sustainability issues (also known as indicators) or/and the interactions among indicators, unintended, negative consequences can occur.

These conclusions are in line with the "integrative", "participatory" and "place-based" nature of "sustainability-scientifically" designed policies. That is, to avoid being fragmented, policies should be designed to address a range of indicators from the outset ("integrative"); in this process, various relevant stakeholders must be engaged ("participatory") and they must be knowledgeable to the context of the sustainability problems concerned so that solutions can be effective ("place-based"). However, in order for the best policies to be effectual, the stakeholders involved must be able to reflect on ways to change certain aspects of their decisions and actions ("reflective").

Since it was shown that integrated policymaking leads to better policies (Kua 2011), it is reasonable to propose using these four adjectives as, at least, a preliminary guide toward improved sustainability policy design. In short, desirable policies should:

1. Address a wide range of sustainability-related issues in an integrated manner (that is, being integrative);
2. Enable stakeholders to participate in designing and/or promoting the deployment of these strategies (that is, being participatory). In other words, we do not consider a policy as being participatory simply because it is applied to a stakeholder (say, an architect is required by law to use energy-efficient design);
3. Encourage stakeholders to reflect and then adjust their actions to achieve better sustainability (that is, being reflective). For example, a "reflective" policy element first assesses the level of energy consumption by building users, then explains the likely sustainability impacts of that consumption before educating them on ways to reduce their consumption; and,
4. Are relevant to the particular places in which they are to be applied (that is, being place-based).

In the present literature, not much has been written on how to apply key concepts of sustainability science to directly influence the design of public policies. Kua (2010) used these 4 adjectives as a guide with which reviewed 66 strategies worldwide under 9 common typologies of strategies (Table 4.1). One should note that the review was not meant to be a critique of the absolute nature of these sustainability strategies; the goal was to indicate possibilities for improvement. The presence of the "integrative", "participatory", "place-based" and "reflective" elements were assessed based on the explicit goal definitions and contents of these strategies.

Table 4.1 Policy strategies reviewed by Kua (2010)

Green building rating systems	(a) Building Research Establishment Environmental Assessment Method (BREEAM); (b) Leadership in Energy and Environmental Design (LEED®) Green Building Rating System; and (c) Green Mark Scheme of the Building and Construction Authority of Singapore.
Green building performance concepts:	(a) Total building performance; (b) Whole-building design (WBD) guide by the National Institute of Building Sciences; and (c) Design for Environment.
Environmental regulations:	Green building regulations of 50 states of the United States.
Product-labeling schemes:	(a) European Union (EU) Eco-label Scheme; (b) EnergyStar label of the Environment Protection Agency (EPA) and Department of Energy (DOE) of USA; and (c) Forest Stewardship Council sustainable wood certification program.
Preferred purchase programs:	USA EPA Environmentally Preferable Purchasing policy.
Incentives for sustainability assessment and procurement:	(a) Singapore's Energy Efficiency Improvement Assistance Scheme (EASe); and (b) Canada's Industrial Building Incentive Program and Commercial Building Incentive Program.
Demonstration projects:	(a) Net Zero Energy Healthy Housing (NZEHH) Pilot Demonstration initiative of Canada
Information portals on sustainable buildings:	(a) Building for Economic and Environmental Sustainability (BEES).
Sustainable urban development concepts:	(a) Ecotrust' Conservation Economy (b) Smart growth theory.

It was found that most of the 50 green building regulations in the United States reviewed contain all four "integrative", "participatory", "place-based" and "reflective" elements. Smart Growth theory, the Forest Stewardship Council Certification programme and the United States Environment Protection Agency (EPA) Environmentally Preferable Purchasing (EPP) policy, present three out of four elements (they all lack the "reflective" element). The remaining strategies all contain two elements with the exception of the two examples of incentive schemes for sustainability assessment/procurement and one example of demonstration project which, due to their specialized nature, were found to be lacking in "integrative", "participatory" and "reflective" elements. For example, out of the 16 non-regulatory strategies reviewed, 9 were found to lack the "integrative" element. This implies that there is a need to improve policies' level of integration – that is, increase the presence of the "integrative" element in these policies.

Thus, this chapter will attempt to embody the "integrative", "participatory", "place-based" and "reflective" elements – in the proposal of integrated design and policy strategies to address climate change identified problems, and any discrepancy between the problems and proposed solutions.

4.2 Research Methodology

The Delphi technique of garnering feedback and opinion from industry experts was employed in this work. It is “a structured group interview technique for seeking consensus among a group about ideas, goals, or other issues” (Jonassen et al. 1999). This technique is often used to forecast needs and to predict future outcomes. Being an iterative research methodology, it allows group participants to modify their previous responses and eventually come to a consensus on an issue or subject matter. Such method will reduce error inherent in individual opinions. The four features that characterize Delphi technique are anonymity, iteration, controlled feedback of responses and statistical aggregation of group members’ responses (Armstrong 2001).

There are several advantages of the Delphi technique over traditional group interviews and focus groups. For one, it can diminish the effects of social pressure, allowing the panel to consider each idea base on merit and not influenced by the social standings of fellow participants. According to Armstrong (2001), this can be achieved through keeping the identity of the individuals anonymous to the others in the panel. As such, the interviews can be conducted through writing without a face-to-face-meeting. Secondly, Delphi technique helps to generate consensus; due to the iterative rounds of interviews and responses of previous rounds being collated and feedback to panel, it allows for the members in the panel to take into account aspects of the problem that has not been considered (French et al. 2001) and eventually come to a consensus as to how the problem should be resolved. In general, it is economical and flexible in nature. As face-to-face meetings are unnecessary, a large number of people can contribute relatively cheaply and easily (French et al. 2001). They are also not restricted in the amount of time they have to speak, as in a focus group, and responses can be made at the convenience of the participant.

However, the Delphi technique is not without any drawbacks. Many academics had criticized the method for several reasons. Firstly, it contains the risk of the facilitator impressing his or her opinion on the group. As group members remain anonymous to one another and the facilitator is required to analyse the inputs from the previous rounds before distributing back to the group, he or she may inevitably impress his or her own view on the group, leading to inaccurate responses from future rounds (Newell 2002). Secondly, the process of deciding who the “experts” are is not straightforward. However, the problem is not exactly problematic as non-experts can also participate in the Delphi Technique without affecting its efficacy. For example, service users were used as the panel in some studies. Thirdly, research participants may be lost; as the Delphi technique consists of several rounds of interview, it is inevitable that some members from the panel may drop out halfway. The panel needs to be well-motivated to follow through the research. Finally, it may be difficult to preserve the momentum of study. Delays need to be kept to a minimum, which is not easy if there is a big group. As many as 45 days may be required for each round.

Despite the various disadvantages of Delphi technique, this technique was still chosen as the research methodology for several reasons. The idea of adapting to climate change in the construction industry is relatively new in Singapore. An overwhelming majority of existing building-related policy is aimed at mitigating climate change, instead of adapting to the likely effects of a changed climate. Since Delphi is a reiterative method, participants are given a chance to ponder upon ideas or points raised in previous rounds and provide a refreshed perspective on them. This is especially useful for an idea not considered before, or one still in its infant stage of development.

In this work, the panel of interviewees consisting of a total of 35 participants was chosen. The participants were project managers, engineers, architects and civil servants from Urban Redevelopment Authority (URA) and Housing Development Board (HDB). The sources of contacts were from the Professional Engineers Boards Singapore 2009, Society of Project managers, the Board of Architect Singapore, URA and HDB. To reduce sampling bias, the names of the participants were drawn out on a list and numbered before they were randomly picked.

A total of three rounds of interviews were conducted. After every round of interview, the responses of the panel were collated and redistributed back to the panel (but without revealing the identities of the other panellists) so as to allow them to gain an understanding of what others in the panel said. Panellists may or may not change their answers in the next round. The interview continued until there was convergence of answers.

In the first round, individual's knowledge of the topic – adaptation to climate change in the construction industry – was examined. These questions were:

1. Do you know the difference between mitigation and adaptation to climate change?
2. What are some of the effects of climate change that will affect the Singapore construction industry?
3. Do you know of any measures/policies/actions/programs that Singapore *is undertaking* to mitigate climate change? Can you provide a few examples?
4. Do you know of any measures/policies/actions/programs that Singapore *is undertaking* to adapt to the effects of climate change? Can you provide a few examples?
5. Based on your experience, what are some of the measures/policies/actions/programs that Singapore can undertake to adapt our construction industry to the changing climate?

Then, the questions in the first round were modified before they were used for the second round, due to revelations from the analysis of the results from the first round. After the second round was implemented, the responses were collated and redistributed back to the panel before the third round so that panellists can choose to make changes to their answers. The questions for these two rounds were the same as the first round; additionally, the following question was asked:

- Do you think that adaptation and mitigation strategies are mutually exclusive? Can you give examples to illustrate your answers?

After the third round, it was observed that there was a convergence of responses from the panel; this means that an additional round of interview will not generate anything new or different, and so the interview was considered as completed. As several rounds of interviews were expected and there is a need to give the panellists the freedom to reply at their convenience, all interviews were conducted through email correspondence. All questions in the interview were intentionally kept open-ended, because there are no preconceived ideas on how Singapore's building stock can adapt to climate change. Open-ended questions also encourage more creativity in the given answers.

4.3 Results

The three rounds of interviews were conducted from September 2009 to December 2009. A total of 35 participants were selected to be part of the panel but eventually only 32 people stayed until the end of the last round of interview. Table 4.2 indicates a relatively equal distribution of panellists among the project managers, engineers, architects and civil servants. Out of the panel of 32, 26 (81.3%) indicated in the first round that they are aware of the difference between adaption and mitigation of climate change. They cited that the use of building elements and/or technologies that help to alleviate the effects and impacts of the changes in the weather are examples of how it is possible to adapt to climate change.

All panellists cited rising temperature as the top concern in the first round of interview, followed by several other effects. However, by the third round of interview, a consensus was reached on three key concerns. The main concerns following effects:

1. Rising temperature that leads to excessive heating, especially in the urban regions (leading to the infamous urban heat island effect);
2. Rising sea level and its effect on the soil erosion in the coastal regions (such as the west coast and marine parade) and even in the green spaces within the urban landscape;
3. Increased incidence of flooding throughout the island, due to the inability of the drainage system to cope with increased volume of flow.

Table 4.2 Distribution of professional background of interviewed panellists

Panellists	No. of panellists selected	No. of panellists who stayed till the end
Project managers	9	7
Engineers	9	9
Architects	9	8
Civil Servants	8	8
Total	**35**	**32**

From the responses, it is clear that almost all the participants are aware that Singapore has measures to mitigate climate change. Out of the 32 participants in the panel, 28 (87.5%) of them indicated in the first round that the GMS is a concerted measure taken by Singapore to mitigate climate change as a result of construction related activities. By the final round, all participants agree that the GMS is indeed the main mitigation measure. The common strategy agreed by the panel is the use of solar panels as a renewable source of energy, the construction of a roof garden and the use of energy-efficient appliances. However, a few provided the feedback that because the cost of solar panels remains high; it is difficult to install them widely and on a large scale.

In the first round of interview, eight participants fed back that they were unsure if the measures they mentioned were adaptation or mitigation measures, as they felt that some of the measures were a combination of the two strategies and there was no clear delineation of which one they belonged to. As a result of this feedback, an additional question was asked in the second round of the interview – as mentioned in the last section, this question is "do you think that adaptation and mitigation strategies are mutually exclusive?". After the third round, a consensus was reached and the panel agreed that the two are not mutually exclusive and certain measures can be *both* adaptation and mitigation strategies. In particular, the panel agreed that the use of solar power is such an example. Another example is the requirement set on the Overall Thermal Transfer Value (OTTV) for buildings (which is also incorporated into the current version of the GMS). The panellist felt that the limit set on the buildings is an adaptation strategy as it allows occupants to stay comfortably indoors even if the outdoor heat is intense. In other words, the occupants are able to adapt to the intense heat outside.

It was observed that answers given to the fourth question in all three rounds of interview were repetitions of the measures that the panellists cited for the question asking on measures taken to mitigate climate change. While two of these – the use of solar energy and limit in OTTV – can serve as both mitigation and adaptation strategies, the rest of the answers given were predominantly mitigation measures instead of adaptation. This could be because Singapore has already made the effort to coordinate mitigation and adaptation strategies and the line between adaption and mitigation is pretty blurred. Another reason for this could be because the panel did not really understand the detailed difference adaptation and mitigation, even though the majority of them stated that they understood the difference between these two approaches. The interviewers then facilitate the idea generation process during the second round by using the responses for the second question – "what are some of the effects of climate change that will affect the Singapore construction industry?" – as a lead. For example, one of the responses given was that there may be increased incidences of flash floods, due to higher rainfall and/or rise in sea level; the interviewers then went on to ask panellists what strategies they think Singapore can implement in the future to adapt building stocks and infrastructures to this particular phenomenon.

The consensus reached during the third round revealed that these strategies were widely considered as essential and effective:

1. Elevating the lowest floor of the building stock to reduce the damages caused by flash flooding;
2. Improving the water-tightness of the building envelope system;
3. Waterproofing of utility systems and building envelope system, and
4. Strengthening foundations to boost resistance to stronger or prolonged floods.

None of the panellists were able to link any of the abovementioned strategies to the widely utilized GMS. This signifies that the present GMS does not offer adequate guidelines on how buildings – existing and newly constructed – can better withstand the potentially detrimental effects of climate change.

4.4 Discussions

Although the 32 industry professionals may not directly influence the climate change policymaking process undertaken by the Singaporean government, the fact that many of the panellists are leaders in their respective field implies that one should still examine closely the implications of their responses. The main findings of this work can be summarized thus:

1. Although the majority of the panellists claimed that they know the difference between mitigation and adaptation strategies, they were not able to readily distinguish between actual construction-related strategies that help to mitigate climate change and those that adapt building stocks and infrastructures to the adverse effects of climate change.
2. Panellists were able to highlight several likely consequences of climate change.
3. The GMS appears to be the most prominent policy that promotes climate change mitigation.
4. The panellists correctly pointed out that adaptation and mitigation are not mutually exclusive; in fact, certain strategies perform the dual function of mitigating and adapting building stocks and infrastructures to climate change.
5. Panellists were unable to propose strategies for adapting to what they considered as the most likely consequences of climate change. More specifically,

   (a) Although they identified the inadequacy of the present drainage system as a cause of the flash flooding in the future, the consensus did not include any insight on how the design of the present drainage system can be improved.
   (b) Although the possibility of increased soil erosion was mentioned by all the panellists, none of their suggested strategies really explored how building stocks and infrastructures are related to the maintenance of the integrity of the soil on which the structures are erected.

One may characterize the consensus reached with three elements – water, soil and the built environment. In our context, “built environment” refers not only to the buildings but also the neighbouring manmade environment within which the buildings are located; this built environment is embedded in an immediate natural environment, which is in turn partially characterized by water and soil.

It is believed that at the heart of aforementioned problems 5(a) and 5(b) – which can be broadly understood as a de-linking among these three elements – is the predominant mind-set or work culture of many industry professionals in Singapore. Firstly, in Singapore at least, many architects conceptualize building and site designs by considering the overall themes, aesthetics, forms, functions, materials and structural integrity of the structures. Considerations of the form and function of the different parts of the building are closely linked to the created flows – of vehicles and people – around and within the physical design space. This conventional approach typically treats different existing physical and service features of and at the site as given boundaries within which the design and construction are carried out. There is usually no in-depth analysis or thought on how the built structure and environment will cause, and be impacted by, changes to its immediate natural environment. As a result, architects and their teams are very likely to think that the states of the water drainage and the condition of soils around their buildings have little direct effect on their design, if any. Even if they feel that strong relationships exist among these aspects of the urban environment, they may not have a full and rigorous understanding of these relationships.

Structural, electrical and civil engineers form the other key members of a project design team. In Singapore, they commonly play the supporting roles by giving advices to the architectural team in their respective aspects. For example, a structural engineer would suggest ways to implement an architect's vision of the form of a building. Engineers find themselves in the position to propose changes to the design scheme and drafts whenever it is either safe or functionally more effective to do so. It is likely that engineers are not clear about the interactions among the said three elements and this may explain their inability to advise future strategies to address the probable water-related problems caused by climate change.

Project managers' roles are usually to realize the actual construction projects, through procuring, management and optimization of the different components of the projects. They usually work according to plans set down by the architects and engineers, and seldom challenge the design team's thinking and assumptions unless it affects the efficiency and quality of the construction activities.

Finally, the civil servants in the panel did not include anyone from the Public Utilities Board (PUB), which is in charge of the management of water resources, networks and supplies. Representatives from the Public Works Department (PWD), which is in-charged of the construction of all public infrastructures, were also left out. However, the largest project developer of the country (HDB) and the agency that oversees the overall urban planning of the country (URA) are included. The lack of connections among the three said elements in the responses given by these civil servants may be explained by an existing lack of collaboration between them and the PUB and PWD on possible water-related catastrophes. Another reason may be that, as in the case of the architects and engineers, there is an inability to comprehend the how the three elements influence one another.

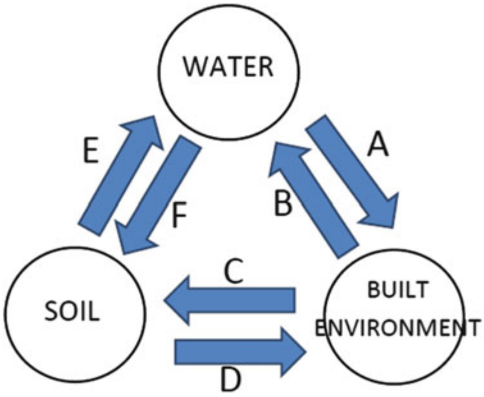

Fig. 4.1 Three design elements of the integrated design concept

4.4.1 Interaction-Based Integrated Building Design

The results of the Delphi study imply that a more integrated design concept for climate change adaptation is needed; the outcome of this design process will then guide and inform the construction activities with the same philosophy of integrating the three elements. Figure 4.1 outlines the key questions regarding the linking up of these three elements (which can now be called the three design elements) – questions that conventional design concepts do not explore:

1. Question A: how might climate change the rainfall patterns in Singapore? How do changes in rainfall patterns affect the effectiveness of the present water drainage system and how do these effects impact the built environment?
2. Question B: how will the choices of building materials, systems and geometry of the built environment affect (or modify) the flow of water around the built site compared to the present situation?
3. Question C: how will the building process and eventual built environment modify the local soil conditions and greenery?
4. Question D: how will the local soil conditions and greenery affect the building process? This constitutes the normal structural engineering consideration for all construction projects in Singapore.
5. Question E: how will the current soil conditions and greenery affect the flow of water around and within the built environment?
6. Question F: how will a change in rainfall patterns give rise to soil erosion, which will in turn modify the flow of water? How can green features such as parks and trees positively change this flow?

Since these questions basically explore the interactions among the three design elements, we called it an *interaction-based integrated building concept*. It is "integrated" because the central tenet involves thinking about at least two of these three design elements at the same time. The underlying assumption is that by answering the six aforementioned questions *iteratively,* the final design product strikes a balance among all the three design elements.

What is required for the industry to promote and enable a change to project delivery process that epitomizes this integrated interaction-based building design concept?

4.4.2 Integrated Policy Directions to Support Transformation to the Interaction-Based Design Concept

Kua (2007) introduced the use of coherently integrated policymaking for conceiving policy approach for sustainable development. In summary, an integrated policy can be understood as one that addresses a wide range of sustainability indicators in all three bottom lines of development (these are the economic, environmental and social aspects) and involving stakeholders across the different levels and areas of operation in the policymaking process. This concept of integrated policy can also be applied in the context of this paper.

Table 4.3 summarizes the five components of policymaking that lead to the formulation of specific policies to promote interaction-based design concept. These five components are as follow, and they were based on the authors' current understanding of the situations that involved the different stakeholders:

1. The key questions linking the three design elements (as posed in the previous section and illustrated in Fig. 4.1).
2. The current situations with regards to these questions.
3. The stakeholders – main and supporting – who should be involved in answering these questions.
4. The engagement platforms; and
5. The likely barriers that may challenge the implementation of these policies.

In summary, we showed that integrated policymaking to address all six key questions (that is, from questions A to F) requires one to engage different stakeholders using different appropriate engagement platforms. Many of the proposed policies require the cooperation of different stakeholders who traditionally do not work together in their professional capacities. It also involves the commissioning of different research and development projects, which explore the combination of different disciplines and looking at the interaction between water, soil and the built environment from different perspectives. It also requires the government to mandate different essential design requirements for the built environment. Most importantly, the policy proposals also underscore the need to combine several policies; this also implies that there are many opportunities for these policies to fail.

It can be noted that different main and supporting stakeholders are involved in addressing the different key questions, although several of them play a role in all six situations. To be truly "integrated" in nature, the policy solutions proposed in Table 4.3, addressing all the six questions, should be brought together in a coherent

Table 4.3 Policies promoting the interaction-based design concept

No.	Key questions	Current situations	Stakeholders involved	Platforms of engagement	Likely barriers & possible solutions
1	Question A: how might climate change alter the rainfall patterns in Singapore? How do changes in rainfall patterns affect the effectiveness of the present water drainage system and how do these effects impact the built environment?	There are neither predictions on how rainfall pattern may change nor different scenarios being drawn up for different policy considerations.	Main: researchers in climate change modelling, meteorology and fluid dynamics. Supporting: PUB, PWD, URA, BCA, architects, engineers and project developers, project managers.	Nationwide call for ideas and project proposals on methods to predict on rainfall. This may involve the use of computer simulation software. Similar simulations can be used to study effects of overflowing of existing drainage systems.	Accurate predictions of rainfall changes and operations of water drainage systems may not be possible (but a reasonable effort is useful). Architects may find it too time consuming to use such software. Mandating its use will promote application of software, which may be created for and co-owned by the PUB and URA.
2	Question B: how will the choices of building materials, systems and geometry of the built environment affect (or modify) the flow of water around the built site compared to the present situation?	It is known that the use of impervious materials for paving roads is a main cause of water runoff, causing flooding. However, understanding of how materials, systems and geometry collectively affect the collection and flow of storm water is still lacking.	Main: researchers in fluid dynamics, building materials and computer simulation. Supporting: PUB, URA, BCA, HDB, architects, engineers and project developers, project managers.	Nationwide call for ideas and project proposals on how use of different building materials and systems affect water flow dynamics. This may involve the use of computer simulation software.	Although this is relatively easier than the abovementioned simulation tool, architects may find it too time consuming to use such software. Similarly, mandating its use will promote application of software, which may be created for and co-owned by the PUB and URA.

(continued)

Table 4.3 (continued)

No.	Key questions	Current situations	Stakeholders involved	Platforms of engagement	Likely barriers & possible solutions
3	Question C: how will the building process and eventual built environment modify the local soil conditions and greenery?	Knowledge in this area can be rather readily built up and collated with the help of structural and geotechnical engineers. However, they may not be used framing and understanding the problems created by the built environment from the perspectives greenery.	Main: architects, structural engineers, geotechnical engineers, botany and landscape architects. Supporting: URA, BCA, HDB, National Park Board (NParks), project developers, project managers.	Organize focus group meeting, followed by expert workshops involving the main stakeholders.	This step is relatively easier. However, land-strapped Singapore may find it difficult to balance between a need for greenery and built-up areas, even to reduce flooding possibilities. Making this it a new and mandatory requirement under the new version of the Green Mark Scheme may help to overcome this problem.
4	Question D: how will the local soil conditions and greenery affect the building process?	This has always been a conventional technical consideration by the structural engineers.	Main: structural engineers and geotechnical engineers. Supporting: Horticulturalists, botanists, BCA, NParks and HDB.	Although this has already been practiced on a regular basis, this question can be built into the focus group meetings and workshops organized for question C above, so that C and D are discussed together in the same activity.	Difficulties may be encountered in trying to marry between answers to questions C and D. For example, construction activities may alter the soil grade and in turn change the water table. If the table is lowered, this may cause drought stress on the trees and shrubs. More creative use of irrigation methods are needed, including using long tubes to draw water from deeper underground to nearer the soil surface in the root zone of plants. Large underground tanks that collect storm water runoff can also be built and these can be used to irrigate greenery in the urban areas.

5	Question E: how will the current soil conditions and greenery affect the flow of water around and within the built environment?	This may be more possible to study for non-built up sites than areas on which existing buildings and/or infrastructure stand.	Main: Geotechnical engineers, landscape architects and Architects. Supporting: BCA, NParks and HDB.	Focus group meetings and workshops involving discussions on question D and B.	Barriers faced by addressing question B may challenge the effort to answer question D. Even if effect on water flow due to constructed features may be known, the combined effects due to greenery (e.g. trees and shrubs) may be more difficult to grasp. A likely solution is to complement computer modelling with physical modelling at designated areas – either in university labs or a government-owned facility – which can transformed into a public demonstration project, or be made into a film and shown in the science centre, at the associated government agencies' exhibition halls or as roaming exhibits to schools.
6	Question F: how will a change in rainfall patterns give rise to soil erosion, which will in turn modify the flow of water? How can green features such as parks and vegetation positively change this flow?	The way soil erosion occurs due to water flows have been widely studied. However, these are mostly macroscopic analyses. Mesoscopic studies correlating water flow to mass reaction of soil, with or without the presence of plant roots are still uncommon.	Main: geotechnical engineers, botanists, researchers in climate change modelling, landscape architects, meteorology and fluid dynamics. Supporting: architects, URA, BCA, HDB, National Park Board (NParks), project developers, project managers.	A combination of platforms proposed above for questions C, D, E and F. In addition, call for research project proposals for the mesoscopic study of soil erosion is needed.	A potential difficulty is that an attempt to combine all these four questions will be crippled by an inability to solve the problems related to questions C, D, E and F separately. Possible solutions proposed for question E may also be applicable here: the conducting of physical experiments and displaying them as public demonstration projects.

and mutually reinforcing way. Creating common platforms of engagement to give stakeholders the opportunity to communicate and interact with one another, as was mentioned in Table 4.3, is not sufficient. Integrated policies that combine them are needed.

What is the role that the general public can play? The general public can be viewed as either future users of the buildings or infrastructure in question, the target of a nationwide educational program on adaptation to climate change, or both. Therefore, combining policies have to engage them in the process of policymaking and implementation as well.

The integrated policies are described as follow:

(a) ***Improvement to the current GMS***

From the consensus, we know that the panellists are all familiar with the role and significance of the GMS. Unfortunately, guidelines specified in the GMS are predominantly mitigation strategies. The mandatory green building standard can certainly be used as the pillar policy tool for instilling adaptation standards into the new and existing building stock; this is especially relevant for new building technologies and techniques (such as new waterproofing techniques that have longer lifespan under tropical conditions). Learning from the transition from the version 3–4 of the GMS (regarding the use of qualified energy simulation software to predict energy performance of new buildings), the BCA – under whose purview the GMS falls– should not be rigidly demanding only certain simulation software to be authorized for addressing questions A and B; but the agency needs to set down minimum standards that these various software must meet.

Given that this is a relatively new direction and expectation of the industry, before these new guidelines are implemented in the future version of the GMS, extensive public feedback opportunities – both online and face-to-face – should be provided. Key industry stakeholders outlined in Table 4.3 should be involved during these feedback sessions. These feedback forums will also be very useful for initiating stakeholders, such as botanists and horticulturalists who are involved in addressing question D, because they are conventionally not directly involved in "greening" the building stocks.

The American Society of Civil Engineers (ASCE) has just introduced a sustainable infrastructure rating system, through the Institute of Sustainable Infrastructure (ISI). Worldwide, many countries are at the stage of extending rating standards beyond buildings to include all infrastructures. It is thus expected that the rating system by ISI will be closely followed by all in the industry. There is a need for the GMS to be extended to include infrastructure as well. To get ready for what many considered as the next stage of action in sustainable cities policymaking, the BCA, URA and HDB must begin discussing ways to adopt Singapore's own infrastructure rating standards and perhaps build these into the existing GMS. Above all, the six questions discussed in this work should also be included within this new infrastructure sustainability rating system.

(b) ***Multi-disciplinary academic research and "citizen-inventor" initiatives***
As explained in Table 4.3 for questions A to F, there are many novel areas of science and technology that have yet to be studied. A suggestion is to make use of the existing research projects and fund management system by the National Research Foundation to initiate more interdisciplinary research proposals in those lines of enquiry outlined in Table 4.3. A type of public outreach has been grossly overlooked so far; forums and competitions for which members of the public can apply and feature their inventive ideas are very rare in Singapore. Alternative, more specialized platforms for public engagement, such "citizen-inventor" initiatives are a good opportunity to garner public feedback and contributions in the area of adapting buildings to the effects of climate change. One existing annual program on which this effort can build is the Tan Kah Kee Young Inventors' Awards. More similar initiatives should be proposed and supported by the private sectors and philanthropic institutions.

(c) ***Professional workshops and skill enrichment programs/courses***
Table 4.2 describes the important roles of various stakeholders. While it is important to get the science and engineering right about how the three elements – water, soil and the built environment – can affect one another, it is more important to be able to communicate the new knowledge to the group of main and supporting stakeholders who will help to apply the knowledge to actual operations. For this purpose, it is necessary to hold multiple rounds of professional workshops, in which stakeholders are taught on the use of the different design software and can participate in the brainstorming sessions to come out with creative solutions to different hypothetical scenarios, using the software as a tool and scientific knowledge created by the researchers as a background. The main objective is to generate different ideas on how the different identified problems can be tackled in a concerted and integrated manner.

The Singapore National Environment Agency (NEA) conducts and manages a series of enrichment courses to train professionals in different environment-related skills, including energy management at the workplace. Design considerations stemmed from stakeholder workshops can later be weaved into a coherent set of curricula that can be imparted to general professionals working in the industry.

(d) ***Public feedback mechanism***
The current version of the GMS does not have a strong public engagement method. Besides having the more specialized form of public engagement, as suggested in (b) above, the incorporation of new knowledge and design methods (including software) into the GMS can serve as a catalyst to "open" up the GMS standards for public scrutiny and feedback at least a year before the implementation of these new standards. In our policy proposals under questions E and F, we suggest engaging the public – even the young – by diffusing the new knowledge via exhibitions and demonstration. Popular platforms, such as science centres, sponsored road shows in shopping malls and roaming demonstrations using vans, can be considered as an effective tool for public outreach and education.

4.4.3 Toward a Generalizable Policymaking Model for Climate Change Adaptation

Although our discussion has been focused on Singapore so far, the underlying methodology can be applied to almost any country. The methodology can be summarized into the following steps:

- Making use of Delphi study to find out the current state of knowledge on adaptation strategies, and projection of problems and desired strategies.
- Identifying the shortcomings and/or inconsistencies between identified problems and proposed solutions. The latter of which is an accurate reflection on the state of professional knowledge of the panellists.
- Transforming these shortcomings into an integrated design concept, aimed at solving the problems that were identified.
- Formulating policy strategies to address the different components of this design concept 4. Formulating integrated policies to bind these diverse policies together within a common framework.

4.5 Conclusions

Given that adaptation strategies are required to complement the best of mitigation strategies, any green growth agenda must include a strong climate change adaptation component. Our Delphi study conducted on a panel of Singapore's building and construction industry professionals indicated that the majority of them cannot clearly distinguish between mitigation and adaptation strategies, and the solutions they proposed for combating the likely consequences of climate change are incoherent with the problems they themselves identified.

In our proposal for an integrated policy strategy, we characterized the problems identified by the panel by three elements and formulated six interconnected questions linking these three elements. In addressing these six questions, we systematically proposed a series of policy solutions involving main and supporting stakeholders, and circumventing some of the identified problems arising from these six questions. In an effort to integrate across all these policies, four integrated policy strategies were identified. It is to be noted that the aforementioned integrated policy strategies are not exhaustive in and of themselves. They serve as examples of how the different information derived from our Delphi study can be utilized for actual policymaking. Finally, a generalized framework of analysis that can be applied to most other countries was also proposed.

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Chapter 5
Analysis of Technical Efficiency and Productivity Using Meta-frontier-Manufacturing Industries in Korea and China

Sang-Mok Kang and Moon-Hwee Kim

Abstract The purpose of this study is to analyze technical efficiency, technology gaps and productivity of the manufacturing industries introducing the meta-frontier model in Korea and China for 2000–2004. We compare technical efficiency ignoring pollution with environmental technical efficiency considering pollution in order to estimate the influence of environmental factors on the competitiveness of manufacturing industries in the two countries. While the technical efficiencies of the Chinese manufacturing industries are higher on average than those of Korea in the two cases (ignoring and considering the pollution), the productivities of the Korean manufacturing industries are higher on average than those of China in both cases. This suggests that the China has a difficulty in reducing pollutants and increasing desirable outputs simultaneously. That is, Korean manufacturing is seemingly closer to sustainable growth than Chinese manufacturing.

Keywords DEA • Directional distance function • Meta-technical efficiency • Meta-productivity • Comparison China-Korea

5.1 Introduction

China, whose annual economic growth rate has been recorded at approximately 10% since its change to reform and openness, is emerging as 'the world's largest manufacturing country'.[1] China's emergence as 'the world's factory' has sent a

[1] *The Financial Times* reported that China will emerge as the world's largest manufacturing country in 2025 year and will outpace the US as a result. This is caused by the ratio of production to the world's manufacturing industries increased from 15% in 2008 to 34.7% in 2025 according to the research of Global Insight which is an economic consultant, located in Washington (http://www.ft.com/cms).

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wake-up call to Korea because the manufacturing industry is still important in leading Korean economic growth. That is, the rapid growth of China, as well as the rapidly changing world economic climate, simultaneously presents an opportunity and a threat to Korea. China has upgraded a number of its manufacturing industries including the heavy and chemical industry, the electrical and electronic industry, and the automobile industry, which are also the main manufacturing industries in Korea. Moreover, the technical gap between Korea and China has decreased gradually since diplomatic relations were established between the two countries. Therefore, to maintain its industry competitiveness ahead of China, Korea needs to introduce measures such as productivity improvement.

Competition among manufacturing industries is influenced by various factors such as prices and the quality of products. Technical efficiency and productivity are included in the indices representing the competition in terms of the efficient use of resources. Technical efficiency measures a relative ratio between a maximum output, and actual output under given inputs. Productivity not only measures the amount that was produced, but also the ratio of output produced to the input used. Thus, productivity is an important element influencing a firm's sustainable growth and competitiveness.

Meanwhile, as interest in the environment has increased sharply both at home and abroad, the more developed industrial economies – such US, Germany, Japan – have not only driven the growth of core industries but also invested in green industries and created new jobs through the promotion of green technologies and environmental regulation. Both China and Korea has begun transformation of the industrial structures for the stimulation of green economic growth and green industries. Environmental efficiencies and environmental productivities of industries are considered as the most important indicators of green growth. Green growth industries should show good performance in terms of environmental efficiency and environmental productivity, just as the general industries should exhibit high efficiency and high productivity to achieve industrial competitiveness.

Hence, this study intends to estimate the environmental productivity including pollution and investigate the environmental productivity gap of the manufacturing industries between the two countries. We compare the environmental productivity with the traditional productivity excluding pollution in order to find the meaning of environmental productivity. Traditional productivity can be derived from the environmental productivity index by excluding pollution factors. In this paper, we intend to empirically analyze technical efficiency, technical gap, and productivity gap between Korea and China, using the meta-frontier concept. If the technical efficiencies and the productivities of the manufacturing industries in Korea and China are measured using the traditional frontier, it is difficult to compare them objectively because the frontiers between both countries are different; however, if we envelope the frontiers of the two countries, it will be advantageous to compare the relative advantage through the meta-technical efficiencies and the meta-productivities. The concept of the meta-frontier has been used to compare the technical efficiency of observations which are in different groups such as industries, regions, or countries.

Battese and Rao (2002) first introduced the concept of the meta-frontier to estimate technical efficiency and technology gap separately, using stochastic frontier analysis (SFA) and data envelopment analysis (DEA) simultaneously. Jemaa and Dhif (2005) also estimated them in 12 MENA (Middle East and North Africa) region's countries, arguing that wars and civil conflicts are restricting agriculture accomplishment in terms of technical efficiency. Rungsuriyawiboon and Wang (2007) estimated the agricultural productivity of 28 provinces in China by separating it into efficiency change, technical change, and scale efficiency change using the meta-frontier, finding that both labor and fertilizer play an essential role in output. O'Donnell et al. (2004) suggested a basic framework to define the meta-frontier and an empirical example of the meta-frontier model through the parametric method as well as the non-parametric method using cross-country' agricultural sector data. Chen et al. (2009) tried to analyze a regional productivity growth in China for 1996–2004, dividing inland provinces from coastal provinces and investigating regional disparities based on productivity.

In this paper, we will examine the technical efficiency, the technology gap, the productivity, and the productivity gap of manufacturing industries in Korea and China during the period 2000–2004, introducing the meta-frontier model of Battese and Rao (2002). Our analysis investigates each individual manufacturing industry in two different countries that may not have the same technology. As mentioned earlier, it may create a bias when adopting the existing frontier model. However, when adopting the meta-frontier model, there is an advantage to conceptualizing the differences among these industries as a technology gap. Furthermore, we try to examine the influence of an environmental factor on the competitiveness of the manufacturing industries between the two countries, which may reflect the fact that an interest in the environment has only recently developed. Through this, we expect to confirm which industry is closer to sustainable growth. This study differs from the existing ones because it combines the meta-frontier model with a frontier model considering an environmental factor. Therefore, this study is significant for being the first to consider environmental factors in the manufacturing industries of Korea and China while adopting the meta-frontier model based on the directional distance function. This paper is organized as follows: Sect. 5.2 presents a theoretical model of the meta-frontier based on directional distance function. Section 5.3 provides the empirical results, and Sect. 5.4 presents the conclusion including political implications.

5.2 Theoretical Model

When explaining the theoretical model, we will explain the measurement of the individual technology and the meta-technology after introducing the relationship between the individual technology and the meta-technology.

5.2.1 Relationship Between Individual Technology and Meta-technology

In general, technical efficiency means a capacity to produce outputs by employing the minimum resources, and the measurement of its efficiency is based on the distance function theory. Let us consider that production can be produced during the periods, $p = 1, \ldots, P$ in the regions K, $k = 1, \ldots, K$ and define $x \in R_+^N$ as input, $y \in R_+^M$ as desirable output, and undesirable output as $b \in R_+^l$. Let us assume that the production function, F(x) is as follows[2]:

$$F(x) = \{(y, b) : \ (x, y, b) : \in \ A\} \tag{5.1}$$

The production possibility set, F(x), is the set of input vector and output vector and it produces the set of output and the pollution, (y, b), which can be produced from input, x.[3] The A in Eq. 5.1 means technology, which is activity transforming inputs given into output. We define the meta-frontier as the entire technology integrating each individual technology. For instance, if a random output, y, is produced using given input vector, x, in a certain region, (x, y, b) belongs to the meta-frontier, A^*.

If a random production point, (x, y, b) is in the technology in a certain region, The technology is expressed as A^k, a subset of A^*. It is defined as follows:

$$A^* \supseteq \left\{A^1 \cup A^2 \cup \ldots \cup A^k\right\} \tag{5.2}$$

Equation 5.2 satisfies the necessary technology axiom since the sub-set (the individual technology) satisfies a technology axiom. That is, meta-technology forms the meta-frontier including these technologies through a convex combination of the technologies in those certain areas. Thus, the meta-technology means the existence of technology (A^*), which takes precedence over all technologies. Each production unit belonging to the region, k, is produced under the individual technology, A^k ($k = 1, 2, \ldots, K$). In this study, we will use the directional distance function in order to measure sustainable growth more suitably. It provides advantages in that it can give different directions such as increase (+) or decrease (−) to desirable output and pollution, respectively. This is defined as follows:

$$\overrightarrow{D_c^k}(x, y, b : -g_x, g_y, -g_b) = \max\{\ \beta : (y + \ \beta g_y, b - \ \beta g_b) \in F_c^k(x - \ \beta g_x)\} \tag{5.3}$$

[2] The production function ignoring pollution is defined as $F(x) = \{(x, y)$: x can produce y$\}$.

[3] According to Fare, Grosskopf, and Pasurka (1986), we assume that the pollution set exhibits weak disposability and the output set exhibits strong disposability. The weak disposability of the pollution can be expressed as $(y, b) \in F(x)$ and $(\beta y, \beta b) \in F(x)$ if $0 \leq \beta \leq 1$. This indicates that a producer should reduce pollution emission and desirable output simultaneously. On the other hand, the strong disposability, producing desirable output while reducing pollution emission freely, can be expressed as $(y, b) \in F(x)$ and $(y', b) \in F(x)$ if $\forall y' \leq y$.

In Eq. 5.3, β indicates the actual value of the directional distance function. When $0 < \beta$, it is inefficient since an observation locates within the frontier. β measures the output level which is extendable on the basis of a point on the frontier in order to reach a maximum output from a real output. On the other hand, when $\beta = 0$, it is efficient as an observation locates on the frontier. The directional vector, g, gives directions to the desirable output and the pollution; here, it gives an increasing direction (+) to output and a decreasing direction (−) to pollution, respectively.

The meta-directional distance function, based on the meta-technology that envelops each individual technology, is defined as follows:

$$\overrightarrow{D_c^*}(x, y, b : -g_x, g_y, -g_b) = \max\{\eta : (y + \eta g_y,\ b - \eta g_b) \in F_c^*(x - \eta g_x)\} \quad (5.4)$$

Equation 5.4 is the meta-directional distance function and is integrated by individual frontiers. The relation between the meta-directional distance function and the individual directional distance function can be expressed as follows:

$$\overrightarrow{D_c^*}(x, y, b) \geq \overrightarrow{D_c^k}(x,y,b),\ k = 1, 2, \ldots, K \quad (5.5)$$

Equation 5.5 derives from the fact that the output set of a certain region is a subset of the output from meta-technology. That is, the technical efficiency of the meta-directional distance function is the same with the individual frontier or it can also be relatively farther away from the individual frontier, compared to the technical efficiency of the individual directional distance function. When a sign denotes inequality (< or >) in Eq. 5.5, it means there is a technology gap between the individual technology of k and the meta-technology. On the basis of the individual distance function and the meta-distance function, the technology gap can be represented as follows:

$$\overrightarrow{TG_c^k}(x, y, b) = \frac{\overrightarrow{D_c^*}(x, y, b)}{\overrightarrow{D_c^k}(x, y, b)} \quad (5.6)$$

The technical efficiency of Eq. 5.6 can be estimated by a relative ratio between the two technical efficiencies. Of course, Eq. 5.6 can also be represented as a multiple of the individual distance function and the technical gap.

5.2.2 *Measurement of the Technical Efficiency and Meta-technical Efficiency*

Generally, the distance function can be measured by using a linear program. If we assume that the observations in the regions, $k = 1, \ldots, K$ produced output,

y_m, m = 1,. . .,M and pollution, b_i, i =1,. . .,I, the linear program for an individual production unit, k, in an individual technology set, A^k, is defined by

$$\overrightarrow{D_c^k}(x_n, y_m, b_i: -x_n,\ y_m, -b_i) = \max \beta$$

$$\text{s.t} \sum_{k=1}^{K} Z^k y_m^k \geq (1+\beta)\, y_m^k,\ \ m = 1,\ \ldots, M,\ \ k = 1, \ldots, K$$

$$\sum_{k=1}^{K} Z^k b_i^k = (1-\beta) b_i^k\ \ i = 1, \ldots, I,\ \ k = 1, \ldots, K$$

$$\sum_{k=1}^{K} Z^k x_n^k \leq (1-\beta) x_n^k\ \ n = 1, \ldots, N,\ \ k = 1, \ldots, K$$

$$Z^k \geq 0 \tag{5.7}$$

The left hand side of the restricted conditions in Eq. 5.7 corresponds with the maximum amount of output and the minimum amount of input, the right hand side of the restricted conditions corresponds with the real amount of output and the real amount of input. These restricted conditions satisfy strong disposability and weak disposability for output and pollution, respectively. Z^k is a weighted density vector. A non-negative density vector indicates that the production technology is a constant return to scale.[4] β gives the value of the directional distance function as the technical efficiency of the directional distance function and has the value from zero(0) to one(1). In Eq. 5.7, the optimal solution can be acquired when output and pollution have the directions of g{x(1 − β), y (1 + β), b (1 − β)}.

Within the left hand side of the restricted conditions, each individual observation vector of inputs and outputs are combined with each weighted vector. The weighted vectors form the maximum amount of outputs and the minimum amount of inputs. The right hand side of the restricted conditions corresponds with the real amounts of outputs and the real amount of input, respectively. On the other hand, the meta-frontier is formed by enveloping each individual frontier. The linear programming of the meta-frontier is represented as

$$\overrightarrow{D_c^*}(x_n, y_m, b_i : -x_n, y_m, -b_i) = \max \eta$$

$$\text{s.t.} \sum_{j=1}^{J} \sum_{k=1}^{k} Z^k y_m^k \geq (1+\eta) y_m^k,\ \ j = 1, \ldots,\ J,\ \ k = 1, \ldots, K$$

[4] The existing studies mainly suppose a certain scale, however, we do not consider the difference accompanied by the different economy scales because the focus of this study is not an economy scale but comparing the technical efficiency and productivity of the manufacturing industries in the two countries.

$$\sum_{j=1}^{J}\sum_{k=1}^{k} Z^k b_i^k \geq (1-\eta) b_i^k,\ i=1,\ldots,\ I,\ k=1,\ldots,K$$

$$\sum_{j=1}^{J}\sum_{k=1}^{k} Z^k x_n^k \leq (1-\eta) x_n^k,\ n=1,\ldots,\ N,\ k=1,\ldots,K$$

$$Z^k \geq 0 \tag{5.8}$$

Equation 5.8 shows the conditions of maximum output and minimum input integrating individual frontiers. Here, η is the actual value of the meta-frontier distance function. The meta-technical efficiency becomes farther away from the meta-frontier because it is much more extended than individual frontiers.

5.2.3 Measurement of Individual Productivity and Meta-productivity

The directional distance function can be defined in the period, p, and the period, p + 1, respectively, and it can be used to estimate technical efficiencies in each period. This directional distance function can also be utilized for measuring the productivity change.

This study intends to compare and analyze the general productivity (Malmquist productivity: hereafter M) excluding pollution, and the environmental productivity (Malmquist-Luenberger productivity: hereafter ML) including pollution separately.

First, the individual productivity growth ignoring pollution can be estimated by using the Malmquist productivity index method as introduced by Färe et al. (1994). The individual productivity growth is estimated in the individual frontier not in the meta- frontier.

The productivity change index, M, can be derived by using four directional distance functions in two different time periods: the directional distance functions in the time period p and p + 1 respectively, from the perspective of time period p technology, and the directional distance functions in the time period p and p + 1, respectively from the perspective of period p + 1 technology. This is derived as

$$\overrightarrow{M_p^{p+1}} = \left[\frac{1+\overrightarrow{D_c^p}(x^p, y^p, 0: g^p)}{1+\overrightarrow{D_c^p}(x^{p+1}, y^{p+1}, 0: g^{p+1})}\ \frac{1+\overrightarrow{D_c^{p+1}}(x^p, y^p, 0: g^p)}{1+\overrightarrow{D_c^{p+1}}(x^{p+1}, y^{p+1}, 0: g^{p+1})}\right]^{\frac{1}{2}} \tag{5.9}$$

In Eq. 5.9, the direction vector, $g = (-g_x,\ g_y, 0)$, is the case that gives the direction disregarding a pollution vector. It means an increase in productivity between the two periods if the productivity change index, M, is greater than one (1), and it indicates a decline in productivity between two periods if the productivity change index, M, is less than one (1).

Similarly, the meta-productivity change index can be derived using the meta-directional distance function as

$$\overrightarrow{M_p^{*p+1}} = \left[\frac{1+\overrightarrow{D_c^{*p}}(x^p, y^p, 0: g^p)}{1+\overrightarrow{D^*}(x^{p+1}, y^{p+1}, 0: g^{p+1})} \frac{1+\overrightarrow{D_c^{*p+1}}(x^p, y^p, 0: g^p)}{1+\overrightarrow{D_c^{*p+1}}(x^{p+1}, y^{p+1}, 0: g^{p+1})} \right]^{\frac{1}{2}} \tag{5.10}$$

Equation 5.10 shows the meta-productivity change index based on the meta-directional distance function, which is defined on the basis of the meta-frontier. With the productivity change index based on regional industries' frontiers in Eq. 5.9 and the meta-productivity change index in Eq. 5.10, the technology gap can be defined by

$$\overrightarrow{MG} = \frac{\overrightarrow{M_p^{*p+1}}}{\overrightarrow{M_p^{p+1}}} \tag{5.11}$$

The meta-productivity change can be divided into the individual productivity growth and the productivity gap. The value of the productivity gap can be either less than, or greater than, one (1). That is, since the productivity change is intended to measure through two different periods, the meta-productivity change can be either less than, or greater than, the individual regional productivity change.

As we have already seen, the M productivity index represents the case of the productivity change excluding the environmental element. In this study, we try to identify the ML productivity change giving the direction to decrease the amount of pollution as the alternative M productivity change. First, the productivity change, including the environmental factor based on an individual frontier, is defined by

$$\overrightarrow{ML_p^{p+1}} = \left[\frac{1+\overrightarrow{D_c^p}(x^p, y^p, b^p: g^p)}{1+\overrightarrow{D_c^p}(x^{p+1}, y^{p+1}, b^{p+1}: g^{p+1})} \frac{1+\overrightarrow{D_c^{p+1}}(x^p, y^p, b^p: g^p)}{1+\overrightarrow{D_c^{p+1}}(x^{p+1}, y^{p+1}, b^{p+1}: g^{p+1})} \right]^{\frac{1}{2}} \tag{5.12}$$

$\overrightarrow{ML_p^{p+1}}$ in Eq. 5.12 estimates the productivity improvement based on the directions not only to abate pollution, but also to augment output, simultaneously. If the pollution abatement activities are not reflected when measuring productivity growth, it may underestimate the productivity and give an incomplete productivity measurement. On the other hand, if the pollution abatement activities are considered as a part of productivity growth, it can give more realistic information about productivity in view of both the disposal of output and pollution.

If the ML productivity change index is greater than one, it means improvement in environmental productivity. However, it means a drop in environmental productivity if the ML productivity change index is less than one. Next, the environmental meta-productivity change can be derived by meta-technology as

$$\overrightarrow{\mathrm{ML}_{\mathrm{p}}^{*\mathrm{p}+1}} = \left[\frac{1+\overrightarrow{\mathrm{D}_{\mathrm{c}}^{*\mathrm{p}}}(\mathrm{x}^{\mathrm{p}},\mathrm{y}^{\mathrm{p}},\mathrm{b}^{\mathrm{p}}:\mathrm{g}^{\mathrm{p}})}{1+\overrightarrow{\mathrm{D}_{\mathrm{c}}^{*\mathrm{p}}}(\mathrm{x}^{\mathrm{p}+1},\ \mathrm{y}^{\mathrm{p}+1},\ \mathrm{b}^{\mathrm{p}+1}:\ \mathrm{g}^{\mathrm{p}+1})}\ \frac{1+\overrightarrow{\mathrm{D}_{\mathrm{c}}^{*\mathrm{p}+1}}(\mathrm{x}^{\mathrm{p}},\mathrm{y}^{\mathrm{p}},\mathrm{b}^{\mathrm{p}}:\mathrm{g}^{\mathrm{p}})}{1+\overrightarrow{\mathrm{D}_{\mathrm{c}}^{*\mathrm{p}+1}}(\mathrm{x}^{\mathrm{p}+1},\mathrm{y}^{\mathrm{p}+1},\mathrm{b}^{\mathrm{p}+1}:\mathrm{g}^{\mathrm{p}+1})}\right]^{\frac{1}{2}} \tag{5.13}$$

Equation 5.13 shows the environmental meta-productivity change on the basis of the meta-frontier, which integrates the individual frontiers. If the environmental meta-productivity change is greater than one (1), it means environmental productivity improvement, while a drop in the environmental productivity is present where environmental meta-productivity change is less than one. The environmental productivity gap can be defined using these two environmental productivity changes as follows:

$$\overrightarrow{\mathrm{MLG}} = \frac{\overrightarrow{\mathrm{ML}_{\mathrm{p}}^{*\mathrm{p}+1}}}{\overrightarrow{\mathrm{ML}_{\mathrm{p}}^{\mathrm{p}+1}}} \tag{5.14}$$

The environmental meta-productivity change can be decomposed into individual productivity change and productivity gap as in Eq. 5.14.

Since productivity change estimates the change in two different time periods, the meta-productivity change can be either greater or less than the individual productivity change. As described above, when the meta-productivity change is greater than the individual productivity change, the productivity gap is greater than one, while the productivity gap is less than one when the meta-productivity change is less than the individual productivity change.

Figure 5.1 represents the relationship between the individual frontier and the meta-frontier, and the individual productivity change and the meta-productivity change. For the convenience of explanation, let us assume that there are only two individual frontiers. We can measure individual technical efficiency based on the individual frontier for each first time period (p), respectively, and derive the meta-frontier enveloping the two frontiers. Measuring technical efficiency with the meta-frontier might differ from measuring it with the individual frontier. Likewise, the meta- productivity change can be estimated on the basis of the meta-frontier for the two time periods. Furthermore, the individual productivity change can be measured on the basis of the individual frontiers between two time periods. The two productivity changes can show which frontiers are farther extended between an individual frontier and a meta-frontier for the two time periods.

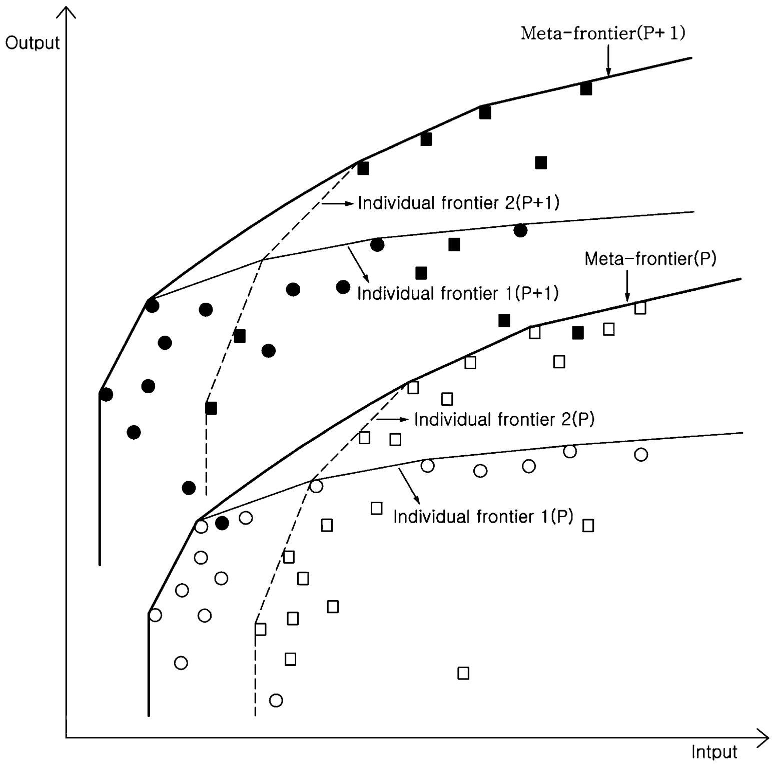

Fig. 5.1 The relation between individual frontiers and meta-frontiers (Modified from Rungsuriyawiboon and Wang 2007)

5.3 Data and Empirical Result

We used the input (labor and capital), output (value added), and pollution (SOx) of the manufacturing industries in two countries for 2000–2004. In China, the statistical data of input and output, and emission amount are available from the Chinese Statistical Yearbook.[5] In Korea, we used the emission amount of SO_x from CAPSS (CAPSS: Clean Air Policy Support System). Monthly labor input amount and

[5] SOx can indicate other air pollutants partially but it cannot reflect levels of water and soil pollutants. However, as China includes only the emission amounts of SOx in the statistical data of pollutants, we use only one pollutant, SOx. Pollutants that are particularly difficult to treat may require additional cost for disposal. But as most of pollutants are usually processed in the same manner, pollutant treatment cost does not vary, regardless of inclusion in pollutant types. That is, pollution control facilities must be operated to treat at least one pollutant with the whole process of pollution treatment regardless of the types of pollutants (Kang and Yoon 2008).

capital stock came from the statistical report of mining and manufacturing industries (2002–2005). The capital stock of each manufacturing industries in China was estimated by accumulating new investment data through the perpetual inventory method.[6] The initial capital stock was estimated by using new investment for initial certain periods and the average growth rate of initial new investment, as in existing studies such as Young (1995).[7] Following Young (1995) we use a depreciation rate of 6%. In this study, we will compare data from 22 manufacturing sectors in Korea with data from 16 manufacturing sectors in China. The classification of manufacturing industries in China is different from the standard industry classification in Korea. The manufacturing industries in Korea – originally classified into 32 sectors – are reclassified into 16 sectors comparable with those of Korea.[8]

Table 5.1 shows the individual technical efficiency, the meta-technical efficiency, and the technology gap, which ignore the impact of the pollution (Sox). The individual technical efficiency excluding pollution in China (0.879) is higher than that in Korea (0.722). Kang and Yoon (2008) explained that the Chinese manufacturing industries are more efficient than the Korean manufacturing industries, because the costs of location and production in Korea are much higher than those in China, whereas the quality of physical capital stocks and availability of labor force in China are higher than those in Korea. In Korea, both the tobacco industry and coke-refined petroleum products & nuclear fuel industry show the

[6] Investment in fixed assets from Chinese Statistical Yearbook was used.

[7] Industrialization started in China since 1978 and the new investment was available from the early 1980s. However, we estimated the amount of new investment by extending the terms up to the middle of the 1960s and adopting the average growth rate of the new investment in the 1980s in order to bring them roughly into line with Korea. China has invested mainly in the manufacturing industries, especially in the light industry since its reform and openness. So the new investment in the most of the light industry is zero or near zero before 1978. The estimation formula by the perpetual inventory method is as follows:

$$K(1) = I(1)/(\delta + g)$$

where K(1) is capital stock in the first term, I(1) is new investment in the first term, δ is the depreciation rate, and g is the annual growth rate of new investment in the five initial years. Therefore, continuous capital stocks are calculated by the following formula:

$$K(1) = (1 - \delta)K(t - 1) + I(t),\ t = 2, \ldots, T$$

The same depreciation rate was applied to consistently analyze the capital stocks of two countries.

[8] In order to compare evenly, it is necessary to unify the statistical data of input, output, and pollution. In China, the statistical data of input and output are classified into 16 sectors and that of pollution is presented with 32 sectors. On the contrary, the manufacturing industries are classified into 23 sectors in Korea, with slight difference in each item. Therefore, perfect unification is impossible. Hence, the statistical data of pollution in China is integrated into 16 sectors as they are unified into input and output.

Table 5.1 The meta-technical efficiency and the technology gap excluding pollution (2000–2004 year)

	Types of industries	Meta	Inv.	TG
Korea	Food products and beverages	0.683	0.684	0.999
	Tobacco	1.000	1.000	1.000
	Textiles	0.629	0.631	0.997
	Wearing apparel and fur articles	0.795	0.863	0.921
	Leather, luggage and harness	0.784	0.816	0.961
	Wood and wood products	0.622	0.622	0.999
	Pulp, paper and paper products	0.626	0.626	0.999
	Publishing, printing, and recorded media	0.656	0.661	0.992
	Coke, refined, petroleum products and nuclear fuel	1.000	1.000	1.000
	Chemicals and chemical products	0.680	0.680	0.999
	Manufacture of rubber and plastics	0.650	0.652	0.998
	Non-metallic mineral products	0.628	0.639	0.983
	Basic metal	0.691	0.696	0.993
	Fabricated metal products	0.648	0.658	0.984
	Manufacture of other machinery and equipment	0.688	0.712	0.967
	Other electric machinery	0.702	0.711	0.987
	Audio-visual equipment	0.685	0.739	0.926
	Medical and precision	0.691	0.702	0.984
	Motor vehicles	0.711	0.754	0.944
	Other transport equipment	0.642	0.664	0.967
	Furniture and other manufacturing	0.681	0.691	0.986
	Processing of recycled materials	0.690	0.691	0.998
Average		0.703	0.722	0.974
China	Food products and beverages, tobacco	0.902	0.968	0.931
	Textiles	0.778	0.784	0.993
	Leather and fur products	1.000	1.000	1.000
	Pulp, paper and paper products	0.736	0.766	0.961
	Publishing, printing, and recorded media	0.681	0.727	0.938
	Coke, refined, petroleum products and nuclear fuel	0.927	0.998	0.929
	Chemicals and chemical products	0.632	0.675	0.936
	Medical products	0.686	0.692	0.992
	Chemical fiber	0.832	0.865	0.962
	Manufacture of rubber	0.778	0.797	0.976
	Manufacture of plastics	0.877	0.940	0.933
	Non-metallic mineral products	0.519	0.575	0.902
	Refining and rolling of metal	0.772	0.799	0.967
	Refining and rolling of non-metal	0.829	0.862	0.961
	Metal products	0.940	0.963	0.977
	Machinery and equipment, electric machinery	0.975	0.997	0.978
Average		0.844	0.879	0.960

1. Meta and Inv. in this table mean meta-technical efficiency and individual technical efficiency, respectively while TG stands for technology gap
2. The average was measured by giving a weighted value based on the output (value added)
3. The technical efficiency is efficient if it is zero, however, we use its reciprocal in order to avoid confusing it with the value of productivity (the technical efficiency has the value from zero to one, and it is efficient if it is one in this table)

maximum efficiency (1.000). Wearing apparel and fur products (0.863), leather, luggage and harness (0.816), motor vehicles (0.754), and audio-visual equipment (0.739) are more efficient than the average (0.722). In China, the leather & fur industry shows the maximum efficiency. Coke-refined petroleum products & nuclear fuel (0.998), machinery and equipment, electric machinery (0.997), food products and beverages, tobacco (0.968), metal products (0.963), manufacture of plastics (0.940) are more efficient than the average.

When it comes to the meta-technical efficiency of Korea, tobacco still shows the maximum efficiency. Wearing apparel and fur products (0.795), leather, luggage and harness (0.784), and motor vehicles (0.711) are more efficient than the average. Leather & fur still shows the maximum efficiency, and machinery and equipment, electric machinery (0.975), metal products (0.940), coke-refined petroleum products & nuclear fuel (0.927), food products and beverages (0.902), and manufacture of plastics (0.877) are more efficient than the average (0.844) in China. It is interesting that coke-refined petroleum products & nuclear fuel, machinery and equipment, electric machinery, food products and beverages in China are very close to the maximum efficiency when it comes to the individual technical efficiency. However, the technical efficiency decreased relatively when it comes to the meta-technical efficiency. This means that these industry types are outstanding in terms of the relative technical efficiency under the individual frontier, but the technical efficiency decreased a lot under the meta- frontier that integrates Korea with China.

Comparing the technical efficiencies of the manufacturing industries in both two countries, most of industries in China have a comparative advantage, while Korea shows an advantage in the industries such as coke-refined petroleum products & nuclear fuel, chemicals & chemical products, and non-metallic mineral products. When it comes to the technical gap ignoring the environmental factor, Korea shows maximum efficiencies in the tobacco, coke-refined petroleum products & nuclear fuel industries, whereas China shows maximum efficiency in the wearing apparel and fur products industry.

Meta-technical efficiency is lower than individual technical efficiency, on average, in both the Korean manufacturing industries and the Chinese manufacturing industries. However, the gap between the individual technical efficiency (0.722) and the meta-technical efficiency (0.703) in Korea is lower than the gap between the individual technical efficiency (0.879) and the meta-technical efficiency (0.844) in China. The Korean manufacturing industries annually outperform the Chinese manufacturing industries in terms of the technical efficiency gap excluding the environmental element. This indicates that the individual frontier in Korea is closer to the meta-frontier, and that in China is farther from the meta-frontier. That is, the technical gap shows how far the individual frontier is from the meta-frontier; if the technical gap is one (1), it means that the two frontiers are the same. In the case of the Korean tobacco and coke- refined petroleum products & nuclear fuel industries, the frontiers are equal, as their the technical gaps are one (1), while the technical gap in the wearing apparel and fur products industries is the lowest (indicating the greatest disparity between frontiers).

Table 5.2 shows the productivity growth and the productivity gap of the manufacturing industries in the two countries over the same period. While the

Table 5.2 The productivity change and the productivity gap excluding pollution (2000–2004 year)

	Types of industries	Meta	Inv.	MG
Korea	Food products and beverages	1.045	1.045	1.000
	Tobacco	0.968	0.968	1.000
	Textiles	1.038	1.038	1.000
	Wearing apparel and fur articles	1.103	1.095	1.007
	Leather, luggage and harness	1.035	1.028	1.007
	Wood and wood products	1.055	1.055	1.000
	Pulp, paper and paper products	1.038	1.038	1.000
	Publishing, printing, and recorded media	1.023	1.025	0.998
	Coke, refined, petroleum products and nuclear fuel	1.085	1.085	1.000
	Chemicals and chemical products	1.118	1.118	1.000
	Manufacture of rubber and plastics	1.048	1.043	1.005
	Non-metallic mineral products	1.060	1.060	1.000
	Basic metal	1.150	1.150	1.000
	Fabricated metal products	1.078	1.085	0.993
	Manufacture of other machinery and equipment	1.078	1.075	1.002
	Other electric machinery	1.055	1.058	0.998
	Audio-visual equipment	1.108	1.108	1.000
	Medical and precision	1.005	1.000	1.005
	Motor vehicles	1.103	1.103	1.000
	Other transport equipment	1.090	1.090	1.000
	Furniture and other manufacturing	1.075	1.070	1.005
	Processing of recycled materials	1.143	1.143	1.000
Average		1.086	1.086	1.000
China	Food products and beverages, tobacco	0.975	0.965	1.010
	Textiles	0.980	0.985	0.995
	Leather and fur products	0.815	0.815	1.000
	Pulp, paper and paper products	0.975	0.975	1.000
	Publishing, printing, and recorded media	1.010	1.015	0.995
	Coke, refined, petroleum products and nuclear fuel	0.993	1.010	0.983
	Chemicals and chemical products	1.095	1.068	1.026
	Medical products	0.960	0.968	0.992
	Chemical fiber	1.075	1.100	0.977
	Manufacture of rubber	0.988	0.988	1.000
	Manufacture of plastics	0.940	0.943	0.997
	Non-metallic mineral products	0.925	0.923	1.003
	Refining and rolling of metal	1.048	1.048	1.000
	Refining and rolling of non-metal	0.993	1.003	0.990
	Metal products	0.903	0.908	0.994
	Machinery and equipment, electric machinery	0.850	0.855	0.994
Average		0.966	0.966	1.000

1. Meta and Inv. in this table mean meta-productivity and individual productivity, respectively while MG means productivity gap
2. The average was estimated by giving a weighted value based on the output (value added)
3. The productivity change was estimated by a weighted value which was acquired as taking the geometric mean between the period, p and the period, p + 1

technical efficiency compares the different production units in a single time period, the productivity growth represents the degree of the productivity change in two different time periods. Here, we divide the productivities into the individual productivity change by the individual frontier, and the meta-productivity change by the meta-frontier, and the productivity gap between the two productivities.

By happenstance, the annual meta-productivity changes of both countries on average are the same as the productivity changes within each country's frontier itself. The individual productivity and the meta-productivity of Korea showed 1.086 on average, respectively. That is, the annual average growth of Korea is 8.6%. . On the other hand, the individual productivity and the meta-productivity of China are 0.966 on average, respectively. That is, China shows an annual productivity decline 3.4% on average, implying that while the manufacturing industries in Korea have contributed to the rapid expansion of the frontier annually, in China they have not.

Taking a closer look at each individual industry, certain types of manufacturing industries of Korea including basic metal (1.150), processing of recycled materials (1.143), chemicals and chemical products (1.118), audio-visual equipment (1.108), motor vehicles (1.103), wearing apparel and fur products (1.095) and other transport equipment (1.090), showed productivity improvement, all higher than the average. These were the same types of industries when it comes to both individual productivity and meta-productivity. However, the meta-productivity growth is relatively lower than the individual productivity growth in the cases of publishing, printing & recorded media, and assembling metal products, and other electric machinery.

On the contrary, the individual productivity growth is relatively higher than the meta-productivity growth in the cases of rubber and plastics, other machinery and equipment, medical and precision, furniture and other manufacturing. On the other hand, nearly half of manufacturing in China industries such as chemical fiber, chemicals and chemical products, refining and rolling of metal, publishing, printing & recorded media, and coke- refined petroleum products & nuclear fuel are higher than the average in terms of the individual productivity. Among them, chemical fiber (1.100), chemicals and chemical products (1.068), refining and rolling of metal (1.048), publishing, printing & recorded media (1.015), coke, refined, petroleum products (1.010), non-metallic mineral products (1.003) and so on, showed improvement in terms of productivity growth.

However, in the case of China, the meta-productivities of just a few types of industries such as food products and beverages, tobacco, and non-metallic mineral products are higher than the individual productivity. That is, the meta-productivity is relatively low compared to the individual productivity growth in most types of industries. Therefore, the Korean manufacturing industries show productivity improvement at an annual rate of 8.6%, while the Chinese manufacturing industries show productivity decline at an annual rate of 3.4% in terms of the productivity excluding pollution. Each individual frontier and each meta-frontier in both countries are almost identical as shown by the productivity gap of 1.000.

Table 5.3 The meta-technical efficiency and the technology gap including pollution (2000–2004 year)

	Types of industries	Meta	Inv.	TG
Korea	Food products and beverages	0.677	0.680	0.996
	Tobacco	1.000	1.000	1.000
	Textiles	0.626	0.632	0.989
	Wearing apparel and fur articles	0.858	0.859	0.999
	Leather, luggage and harness	0.815	0.824	0.988
	Wood and wood products	0.617	0.619	0.997
	Pulp, paper and paper products	0.626	0.629	0.995
	Publishing, printing, and recorded media	0.664	0.664	1.000
	Coke, refined, petroleum products and nuclear fuel	1.000	1.000	1.000
	Chemicals and chemical products	0.678	0.678	1.000
	Manufacture of rubber and plastics	0.644	0.651	0.989
	Non-metallic mineral products	0.637	0.648	0.982
	Basic metal	0.685	0.685	1.000
	Fabricated metal products	0.644	0.645	0.998
	Manufacture of other machinery and equipment	0.685	0.685	1.000
	Other electric machinery	0.702	0.702	1.000
	Audio-visual equipment	0.775	0.775	1.000
	Medical and precision	0.710	0.710	1.000
	Motor vehicles	0.766	0.766	1.000
	Other transport equipment	0.691	0.691	1.000
	Furniture and other manufacturing	0.687	0.688	0.998
	Processing of recycled materials	0.670	0.670	0.999
Average		0.724	0.726	0.997
China	Food products and beverages, tobacco	0.929	1.000	0.929
	Textiles	0.776	0.777	0.998
	Leather and fur products	1.000	1.000	1.000
	Pulp, paper and paper products	0.788	0.795	0.991
	Publishing, printing, and recorded media	0.788	0.921	0.856
	Coke, refined, petroleum products and nuclear fuel	0.978	1.000	0.978
	Chemicals and chemical products	0.631	0.723	0.873
	Medical products	0.686	0.692	0.990
	Chemical fiber	0.836	0.847	0.987
	Manufacture of rubber	0.779	0.789	0.987
	Manufacture of plastics	0.919	1.000	0.919
	Non-metallic mineral products	0.816	0.816	1.000
	Refining and rolling of metal	0.805	0.812	0.991
	Refining and rolling of non-metal	1.000	1.000	1.000
	Metal products	0.956	0.965	0.991
	Machinery and equipment, electric machinery	1.000	1.000	1.000
Average		0.874	0.903	0.968

The individual technical efficiency, the meta-technical efficiency, and the technology gap considering pollution are shown in Table 5.3. The individual technical efficiency of China (0.903) is higher than that of Korea (0.726), even in terms of technical efficiency including pollution. In the case of Korea, tobacco, and coke- refined petroleum products & nuclear fuel showed the maximum efficiency of 1.000. Wearing apparel and fur products (0.859), leather, luggage and harness (0.824), audio-visual equipment (0.775), and motor vehicles (0.766) are more efficient than the average. In China, food products and beverages, tobacco, leather and fur manufacturing, coke, refined, petroleum products & nuclear fuel, manufacture of plastics, non-metal products, and machinery, equipment & electric machinery showed the maximum efficiency. Metal products (0.965) and publishing, printing & recorded media (0.921) are more efficient than the average. China (0.874) is higher than Korea (0.724) even in terms of the meta-technical efficiencies considering pollution.

When it comes to meta-technical efficiency, in the case of Korea, tobacco, and coke- refined petroleum products & nuclear fuel showed the maximum efficiency, as in the individual technical efficiencies. Wearing apparel and fur products (0.858), leather, luggage and harness (0.815), audio-visual equipment (0.775), and motor vehicles (0.766) are more efficient than the average (0.724). In the case of China, coke, refined, petroleum products & nuclear fuel (0.978), metal products (0.956), food products and beverages & tobacco (0.929), and plastics (0.919) are more efficient than the average (0.874), whereas leather and fur, non-metal products, and machinery, and equipment & electric machinery showed the maximum efficiency.

Comparing the technical efficiencies of both countries' manufacturing industries based on the meta-frontier, most of the manufacturing industries in China have an advantage when pollution is excluded. However, Korea still has an advantage for tobacco, and coke-refined petroleum products & nuclear fuel. The technical efficiencies including pollution in the industries such as wearing apparel and fur articles, leather, luggage and harness, and motor vehicles showed higher improvement than the technical efficiency excluding pollution.

In the case of China, the technical efficiencies considering pollution in the industries such as non-metallic mineral products, refining and rolling of metal, and refining and rolling of non-metal show higher improvement than the technical efficiency excluding pollution.

When it comes to the technical gap, in the case of Korea, nearly half of the manufacturing industries including tobacco, and coke-refined petroleum products & nuclear fuel, and chemicals and chemical products recorded high performance, whereas, in the case of China, only a few types of industries such as leather and fur products, refining and rolling of metal, refining and rolling of non-metal, and machinery- equipment and electric machinery showed high performance. This suggests that Korean manufacturing industries satisfy the conditions of sustainable growth, although they show lower performance than those in China. Regarding the meta-frontier, the technical efficiencies including pollution in Korea and China show improvement of 2.1% and 3.0% on average, respectively, compared to the general technical efficiencies.

The technical efficiencies including pollution become greater than the technical efficiencies excluding pollution, because the production possibility curve shrinks when considering pollution abatement activities in terms of resource substitution.

The meta-technical efficiencies regarding pollution in both Korea and China represent lower levels than the individual technical efficiencies in both countries on average. However, the gap between the individual technical efficiency (0.726) and the meta-technical efficiency (0.724) in Korea is comparatively lower than the gap between the individual technical efficiency (0.903) and the meta-technical efficiency (0.874) in China. Consequently the technology gap of Korean manufacturing shows 0.997 on average, while the technology gap of Chinese manufacturing shows 0.968 on average. Thus, we see that the frontier of the individual technical efficiency in the Korean manufacturing industries is closer to the meta-frontier rather than the frontier of the individual technical efficiency in the Chinese manufacturing industries.

Table 5.4 shows the productivity change and the productivity gap of the manufacturing industries, considering pollution. Based on the individual productivity change and the meta-productivity change, Korea shows annual average growths of 2.5% (1.025) and 1.5% (1.015), respectively. This is a lower level relatively compared to the case ignoring pollution (1.086).

While China shows an annual average growth of 0.2% (1.002) in terms of individual productivity, it shows an annual average decline of 0.9% in terms of meta-productivity. However, this value is higher compared to the case excluding pollution. This also suggests that, whereas the manufacturing industries in Korea have contributed to the rapid extension of the frontier annually, those in China have not. That is, the environmental productivity reflecting the pollution abatement activities in Korean manufacturing industries have increased significantly compared to those in the Chinese manufacturing industries for the same period. The Chinese meta-productivity growth including pollution, except for chemical fiber, chemicals and chemical products, has increased more than that excluding pollution. This implies that China has made an effort to seek pollution abatement activities as well as economic growth simultaneously since 2000.[9]

Taking a closer look at this, nearly half of all types of Korean manufacturing industries showed more meta-productivity improvement than the average (1.015). They fall on fabricated metal products (1.048), leather, luggage and harness (1.039), other transport equipment (1.036), furniture and other manufacturing (1.035), manufacture of rubber and plastics (1.031), medical and precision (1.031), chemicals and chemical products (1.025), and processing of recycled materials (1.020) and so on. These industries make up nearly half of the Korean manufacturing industries.

On the other hand, the Chinese manufacturing industries which showed productivity improvement in terms of meta-productivity were non-metallic mineral products (1.173), refining and rolling of non-metal (1.130), chemical fiber (1.023), refining and rolling of metal (1.023), publishing, printing, and recorded media (1.020),

[9] The Chinese government has been interested in international environmental protection since the Earth Summit in 1992. The Chinese government started to conduct the maintenance and revision of the environmental laws and regulations after the year 2000, even though the Chinese government promoted the environmental laws and regulations gradually after the middle of 1990s.

Table 5.4 The productivity change and the productivity gap including pollution (2000–2004 year)

	Types of industries	Meta	Inv.	MLG
Korea	Food products and beverages	1.009	1.011	0.998
	Tobacco	1.012	1.006	1.006
	Textiles	1.006	1.007	0.999
	Wearing apparel and fur articles	1.008	1.038	0.970
	Leather, luggage and harness	1.039	1.007	1.032
	Wood and wood products	1.009	1.010	0.999
	Pulp, paper and paper products	1.010	1.007	1.004
	Publishing, printing, and recorded media	1.007	1.005	1.003
	Coke, refined, petroleum products and nuclear fuel	1.005	1.005	1.000
	Chemicals and chemical products	1.025	1.031	0.994
	Manufacture of rubber and plastics	1.031	1.010	1.021
	Non-metallic mineral products	1.010	1.009	1.002
	Basic metal	1.014	1.048	0.967
	Fabricated metal products	1.048	1.019	1.028
	Manufacture of other machinery and equipment	1.020	1.021	0.999
	Other electric machinery	0.998	1.017	0.982
	Audio-visual equipment	1.015	1.032	0.984
	Medical and precision	1.031	1.000	1.032
	Motor vehicles	1.000	1.036	0.965
	Other transport equipment	1.036	1.048	0.988
	Furniture and other manufacturing	1.035	1.020	1.015
	Processing of recycled materials	1.020	1.042	0.979
Average		1.015	1.019	0.996
China	Food products and beverages, tobacco	0.988	1.001	0.987
	Textiles	0.973	0.974	0.999
	Leather and fur products	0.989	0.990	0.999
	Pulp, paper and paper products	0.977	1.015	0.962
	Publishing, printing, and recorded media	1.020	1.066	0.957
	Coke, refined, petroleum products and nuclear fuel	1.009	0.991	1.018
	Chemicals and chemical products	1.018	1.014	1.004
	Medical products	0.987	0.998	0.989
	Chemical fiber	1.023	1.023	1.000
	Manufacture of rubber	1.001	1.005	0.996
	Manufacture of plastics	0.945	1.006	0.940
	Non-metallic mineral products	1.173	1.039	1.129
	Refining and rolling of metal	1.023	1.022	1.001
	Refining and rolling of non-metal	1.130	0.951	1.188
	Metal products	0.997	1.029	0.969
	Machinery and equipment, electric machinery	0.934	0.998	0.935
Average		0.991	1.008	0.984

coke- refined petroleum products & nuclear fuel (1.009), chemicals and chemical products (1.018), and so on.

Consequently, while the Chinese manufacturing industries showed an annual average decline of 0.9% (0.991) in terms of the meta-productivity, the Korean manufacturing industries showed an annual average growth of 1.5% in terms of the meta-productivity. Moreover, the technology gap (including pollution) of Korea showed 0.991, slightly higher than that of China (0.989).

The results of this study are similar to those of Lee et al. (2008). Even though they compared the Korean manufacturing industries with Chinese manufacturing industries, using the individual frontier, they insisted that the technical efficiency of the Korean manufacturing industries (0.74 on average) was lower than that of Chinese manufacturing industries on average. Furthermore, in their study, Korea demonstrates an advantage in the manufacturing industries such as coke-refined, petroleum products & nuclear fuel, chemicals and chemical products, and non-metallic mineral products. China has an advantage in most manufacturing industries, with the exception of the chemical and non-metallic mineral products sectors. It seems that there are differences of analysis periods and approaches, in terms of the non-parametric meta-frontier and the parametric individual frontier between this study and Lee et al. (2008).

5.4 Conclusion

In this study we empirically examined the individual technical efficiency, the meta-technical efficiency, the productivity change and the meta-productivity change for both the Korean and the Chinese manufacturing industries, distinguishing the case including pollution from that excluding pollution.

Based on the meta-technical efficiencies of two cases including and excluding pollution, most of the Chinese manufacturing industries have an advantage over the Korean manufacturing industries, which have an advantage only in the coke-refined petroleum products & nuclear fuel manufacturing, chemicals and chemical products. Fortunately, the meta-productivities of the Korean manufacturing industries were higher than those of Chinese manufacturing industries regardless of whether pollution was considered or disregarded.

By applying the meta-frontier, an important finding is that there exists a significant difference between two technical efficiencies in the individual frontier and the meta-frontier. The meta-technical efficiencies are lower than the individual technical efficiencies. Other differences are that the meta-productivity changes reflecting pollution are lower than the individual productivity changes considering pollution in two countries, and that the meta-productivity changes reflecting pollution of China were more pronounced than meta-productivity changes reflecting pollution of Korea. This suggests that using the individual frontier for estimating technical efficiencies and productivity changes may lead to distorted results.

Given the rapid growth of the Chinese manufacturing, Korea should specialize to greater degree in the comparatively advantageous industries and the technical innovation through adoption of new technology and investment of R&D to promote the productivity and the efficiency of Korean manufacturing industries.

Furthermore, innovation is urgently needed in machinery, technology, training skills, production systems, and business institutions and circumstances.

As shown in empirical tests, the advantages in the Chinese manufacturing industries gave a wake-up call to the Korean manufacturing industries. Then, if the environmental regulations are gradually strengthened with the reinforcement of international environmental regulations in China, there might be a possibility to offset the situation because of the increasing environmental cost in the Chinese manufacturing industries. However, the influence would be not significant as we could see in the technical efficiencies considering pollution. In order to be less influenced by the effect of the Chinese manufacturing industries, the important thing is that the Korean manufacturing industries need to differentiate themselves from the Chinese manufacturing industries, by seeking higher quality through technical innovation, and specializing in areas of technology such as medical and precision, audio-visual, motor vehicles, machinery and equipment, and electrical machinery. These specializations in the manufacturing industries should be accomplished by harmonization with the entire Korean industrial structure.

Ultimately, it is very important that the Chinese industries as well as the Korean truly devote their efforts to the green growth, moving away from a growth strategy giving sole priority to the economy. By the same token, the manufacturing industries in the two countries should move from the pollution industries and the energy-intensive industries to the high-tech industries and the service industries in order to create true green growth industries. They should also combine the green technology with their traditional technology, and turn their concerns to the green industries. The main limitation of this study is that we could not precisely match the two countries' industries through longer time periods since the proper classifications of industries and the complete data for pollution was not available for China.

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Chapter 6
Green Growth Index and Policy Feedback

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Abstract Using a system dynamics model, we compute the realized environmental investment rate. Using this rate as the weight, the green welfare index is computed from the consumption index and environmental services index. The environmental investment rate that maximizes the present value of the future stream of green welfare indices is estimated and called the optimal environmental investment rate. The normalized gap between these two rates is called 'green growth gap,' which gauges the deviation of the economy from the dynamically optimal path. The Green Growth Index is also developed to express this concept in a more digestible manner. These concepts and index are expected to be useful in the performance assessment of the national green growth strategy. This chapter provides a system dynamics model that can serve as a basis for measurement and policy feedback for green growth as a national strategy of Korea.

Keywords Green growth gap • Green growth index • Environmental investment rate • Weight • Korea

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6.1 Introduction

Despite some conceptual vagueness, 'green growth' is set as a national agenda in Korea. At the core of this agenda is mitigating climate change. Although Korea is not an Annex I country, President Lee declared Low Carbon Green Growth as a national agenda in 2008. Korea has announced a long-term strategy that will determine the direction of its national environmental and energy policy until 2030 – and possibly for the next 60 years. The emission target is reduction by 30% from BAU until 2020. Alongside this, legal/institutional arrangements – Green Growth Basic Act and its Ordinance – is established (Han et al. 2009).

Although the concept of green growth became an official term for Korea's national strategy, this term is not distinctively clear. Sometimes it is considered as a synonym for eco-efficiency improvement.[1] In some cases, it passes by as a loosely defined group of investment program related to the environment. In 2007, UNEP published a report on Korea's green growth strategy, which focuses on an overall package of various policies and programs. These include nuclear power plants and the Four Major River Restoration Projects,[2] which are controversial both for their greenness and for economic feasibility. In this paper, the green growth is considered as a dynamic national strategy, which uses environmental regulation as a source of market creation and technology development.

Therefore, the crucial question centering on green growth is how strong the environmental policy/regulation should be. Environmental regulations primarily hinder economic growth with higher costs. On the other hand, as a second effect, regulations create green demand and incentives for green technology innovation.[3] These two effects combined may result in net positive effect on economic growth. Furthermore, without appropriate environmental regulations, a country might fail to capitalize on newly emerging markets. Still, tougher environmental policies/regulations may likely impose unbearable economic burden, eventually resulting in slower economic growth. To avoid economic underperformance with stricter environmental regulations, the government should design and implement a smart policy package that is dynamically relevant. For such purpose, performances should be measured and evaluated in a dynamic context.

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[1] See Chung (2008).

[2] The Four Major River restoration Project is a multi-purpose project being concurrently implemented in Han, Nakdong, Geum and Youngsan Rivers. This project was initiated as part of the Green New Deal Policy of the Korean government and its estimated total cost is 22.2 trillion won, approximately 17.3 billion USD. For more information see Han et al. (2011).

[3] For this line of discussions, refer to Gerlagh and Keyzer (2003), Gerlagh and van der Zwaan (2003), and Goulder and Schneider (1999). Also refer to Cho and Na (2004) for a discussion in the Korean context.

6.2 Green Growth, Green Growth Index, Environmental Investment, and 'Green Growth Gap'

Green growth means an environmental-economic strategy wherein – by sacrificing current consumption level – an economy can increase future consumption and environmental services; hence the higher welfare level over time. In other words, green growth is a dynamically optimal growth path that considers the environment explicitly. Here, the key policy variable is the 'environmental investment rate,' which is the rate of all environment-related investments including the cost incurred due to the environmental regulations. If the 'environmental investment rate' is too low or too high, the economy will deviate from the optimal growth path and fail to attain a dynamic optimum. This paper attempts to estimate the realized environmental investment rate and the dynamically optimal environmental investment rate at the same time. The gap between the two can be called 'green growth gap.'

A system dynamics model is constructed to determine the weight given to the environmental index, consumption index, and dynamic policy index[4] in computing the green welfare index and green growth index.[5] This system dynamics model simulates the growth paths for the Korean economy. The model contains both economic and environmental variables. Using a system dynamics model, we compute the realized environmental investment rate (w_1'), defined as the rate that minimizes the sum of squared errors of simulated values from real data on the various variables making up the system. The green welfare index is a weighted sum of consumption index and environmental services index with the realized environmental investment rate used as the weight given to the environmental services index. The environmental investment rate that maximizes the present value of future stream of green welfare indices is estimated and called the optimal environmental investment rate (w_1*). The normalized gap between these two rates (w_1'/w_1*) is called 'green growth gap.' This gauges how much the current growth path deviates from the optimal dynamic path. Therefore, the green welfare index, which measures the welfare level but does not consider optimality in a dynamic sense, needs to be adjusted using this gap. When adjusted using the green growth gap, the green welfare index is converted into the green growth index. At this time, the weight given to the environmental services index – in computing the green welfare index – means the relative value of environmental service to consumption. Therefore, the realized environmental investment rate being used as the weight requires assuming that higher investment in the environmental sector in society reflects the higher value placed by society on environmental goods.

The process of computing the green growth index is shown in Fig. 6.1.

[4] The dynamic policy index (GDPI) is combined with green welfare index (GWPI) to compute green growth index. More detail is explained in Sect. 3.4.

[5] Green welfare considers both GDP and environmental service together. GWI is the measurement for green welfare.

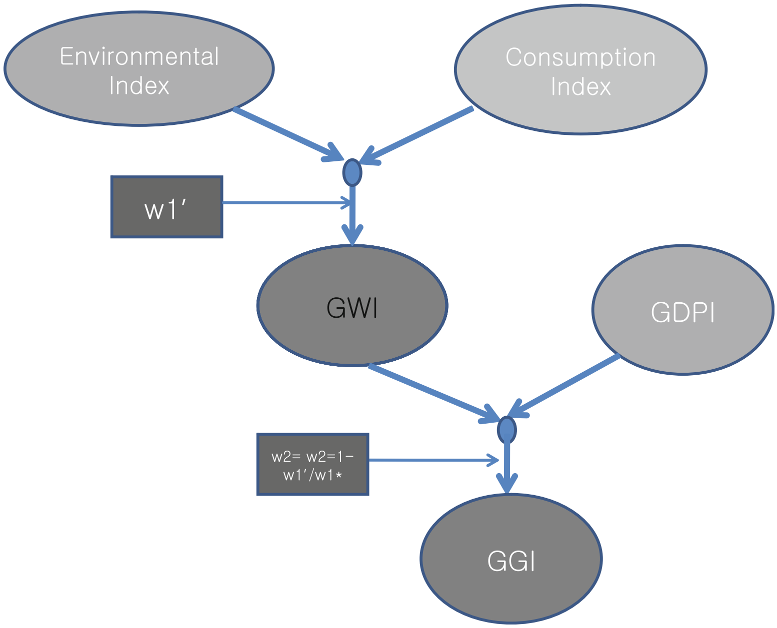

Fig. 6.1 Computing the green growth index

6.3 Structure of the Model

We construct a general equilibrium model consisting of three sectors of sub-modules for the economy, environment, and policy as shown in Fig. 6.2.[6] The economic sub-module captures the interrelationships among capital stock including depreciation, capital formation, GDP, pollution function, consumption, and investment. The environmental sub-module consists of the environmental stock, which is determined by the flow of pollution and flow of environmental augmentation (*aug_flow*), and the environmental technology stock determined by research and development for environmental improvement (*Env_R&D*). Pro-environmental activities (*Env_Activity*) are also included in the module to derive the effects of environmental expenditure (*Env_Aug_Exp*) and state of environmental quality augmentation (*Env_Augmentation*). Finally, the policy module consists of economic policies (*Econ_Policy*), environmental policies (*Env_Policy*), and Green Welfare Index (*GWI*).

We allow the effects of pollution emissions from producing goods and services on the state of environment, i.e., economy-to-environment path. At the same time, we allow the effects of emission mitigation activities on the environmental industry

[6] For the complete equations of the model, see the Appendix.

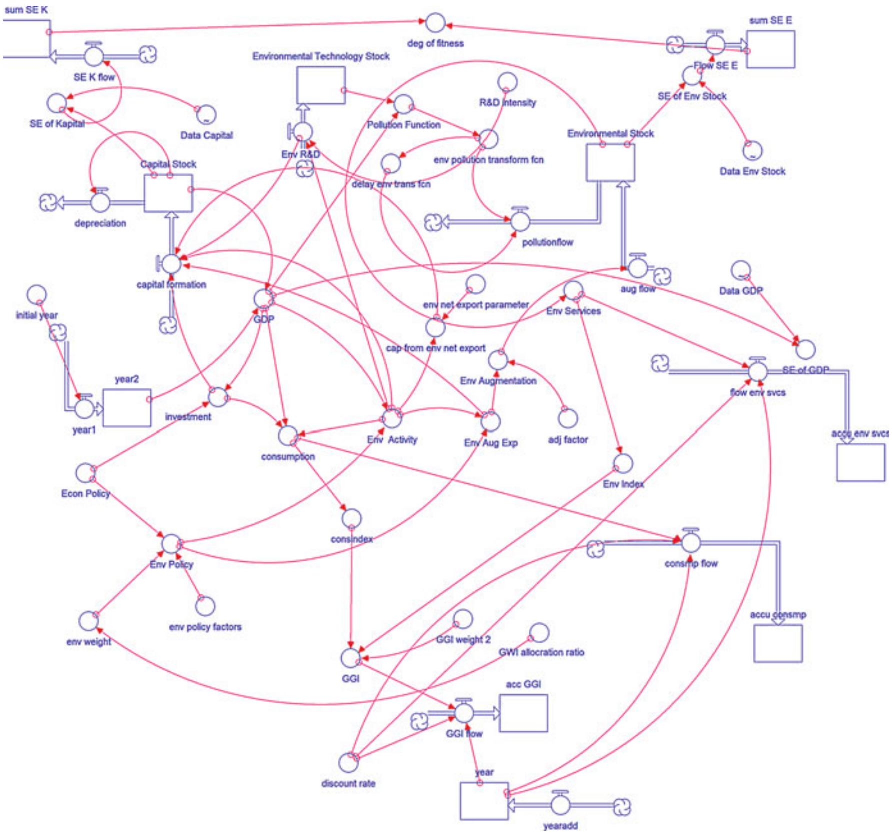

Fig. 6.2 Structure of the Model

as well as indirect feedback effects of environmental policy through the Green Growth Index on the economy, i.e., environment-to-economy path. Note that we disregard the potential effects of environmental stock on the economy such as labor productivity improvement for a simplified model structure.

The performances of the economic and environmental sectors are affected by changes in policy decisions. The economic policy variable in our model is defined as ordinary investment rate out of the gross domestic product (GDP), and the environmental policy variable (as the rate of environmental expenditure out of the GDP). The resources allocated to environmental activities are divided into environmental augmentation, abatement technology innovation, ordinary investment, and foreign sector. Environmental augmentation is referred to as any mitigation of pollution emission. Abatement technology innovation reduces the emission coefficients of production. Ordinary investment here represents the capital accumulation for the environmental industry or any expenditure for complying with the environmental regulation in a broad sense. Resources distributed for the foreign sector are used for developing internationally competitive green goods. Its net export would expand the overall economic performance through the multiplier effect, and the increased performance consequently affects the overall capital accumulation. In other words, the policy module consists of two categories: the economic and the environmental policies. The policy effects are realized by the changes in the shares of consumption, investment, and environmental activities out of the GDP. Finally, the consumption share is automatically determined once the shares for investment and environmental activities have been determined.

6.4 Data and Computation of the Major Indices – Variables

The system dynamics model is based on various variables; these are sometimes metric data but they are also indices computed from several metric data series. The variables in the system dynamics model include environmental index (environmental state variable – stock variable), pollution emission index (a flow variable in the model), consumption index (a flow variable, mainly composed of consumption level) and capital stock. These variables interact with each other. Environmental index, pollution emission index, and consumption index are computed from available data, using a statistical method of principal component analysis (PCA). For capital stock, the capital stock data itself is used instead of index.

Environmental index (*environmental_stock* in the system dynamics model) summarizes the state of the environmental services of Korea. It is considered as a stock variable in the system dynamics model. Environmental service, as a flow variable, is generated from this variable by multiplying a constant rate. In computing environmental index, many variables are selected from the air quality and climate sector. It includes the maximum sulphur oxides (So_x) concentration level, Total suspended particulate matter (TSP) concentration, and surface ozone concentration level. The carbon dioxide (CO_2) concentration level, which is considered as the ultimate indicator variable for 'low carbon green growth strategy,' is included. In the water quality sector, DO (Dissolved Oxygen) is selected, as a representative indicator of water quality. In the land and land use sector, forest coverage ratio is selected to represent the effect of forest on the overall environmental service of Korea. Finally, to represent chemical hazards, the quantity of toxic chemicals in circulation is included. Environmental index is computed from these data sets, using PCA method, avoiding the difficult task of allocating weights to each variable. Weight allocation is often criticized for its arbitrariness. PCA, which is a *de facto* automatic weighting mechanism for each variable, allocates weight to each variable based on its relative variability, where variables with more variability get larger weights. The result of PCA is in the form of score specific to the PCA method. This score is linearly converted to percentage scale, for the comparability with other indices.

Consumption index (*consumption* in the system dynamics model) is computed by combining the variables representing economic welfares, mainly consumption variables. For simplicity and international comparability in the future work, only per capita GDP and household consumption were used. Like environmental index, consumption index, fabricated from basic data using PCA, is transformed to percentage index for the consistency with other indices.

Pollution emission index (*pollution* in the system dynamics model) is generated by combining variables which are "pressure" variables that changes the environmental state variables. This index is a flow variable, while the composite environmental index is a stock variable. This index is computed by way of an intermediate variable that links various industrial and economic activity levels to environmental state variables. This index is composed of only air quality and water quality variables. This is due to the fact that variables other than these subsectors, in Korean environmental statistics, are mainly state variable rather than flow, pressure variables. They include per capita carbon dioxide (CO_2) emission level, sulphur dioxide (SO_2) emission level, and volatile organic compounds (VOC) emission level. Regarding water quality, Biological Oxygen Demand (BOD) emission level is selected. Pollution emission index is computed from these three variables using PCA method. The PCA score was linearly transformed to percentage index.

Environmental technology stock is interpreted as the level of environmental technology resulting from accumulated environmental R&D. It is computed by applying the adjusted R&D share in the budget of Ministry of Environment (2005–2007). In short, environmental technology stock is the accumulated environmental R&D flow, which is computed by applying a fraction on the environmental budget.

GDPI (Green Dynamic Policy Index) is an index that represents Korea's overall effort to internalize environment into economic decision making. It is composed of recycling rate and PAC (pollution abatement and control expenditure) to GDP ratio. GDPI is not included in the system dynamics model. It is used to compute the final GGI by weighting with w_2 (= $1 - w_1'/w_1^*$), which is estimated from the system dynamics model. When w_2, 'the green growth gap,' is equal to zero, GGI is identical to GWI, since current GWI level is dynamically optimal. When w2 gets larger, the weight of GWI gets smaller and the weight for GDPI gets larger. In this situation, current welfare level is not optimal and policy response level (GDPI) becomes more important in evaluating the current dynamic optimality.

6.5 Empirical Estimation of the Model

To run our economy-environment system dynamics model, we need to approximate as closely as possible most of the parameters describing the current economic reality. This section deals with empirically estimating equations for capital stock, environmental stock, and environmental technology stock in the model.

First, capital_formation was estimated as in Eq. 6.1. This equation shows that capital formation (increment flow in capital, *Capital_formation*) is generated from some portion of investment in non-environmental sector *(investment)*, and capital generated form the environmental activity *(Env_Activity - Env_R&D - Env_Augmentation_expenditure),*[7] and capital formed from net export of environmental industry.

$$\begin{aligned}\textbf{Capital\_formation} =& \textbf{investment}^{*}\,\textbf{0.449} + \textbf{Env\_Activity} - \textbf{Env\_R\&D} - \\ & \textbf{Env\_Augmentation\_expenditure} + \textbf{cap\_from\_env\_net\_export}\end{aligned} \tag{6.1}$$

Eq. 6.2 is production function where capital stock is assumed as the only factor. This simplification is based on the premise that labor input is stable and no change occurs in labor productivity over the simulation time period. The economy produces the final output, i.e., GDP, by utilizing the capital stock based on the production technology expressed in Eq. 6.2. We apply the year variable (year 2) to include the effect of annual technology innovation over the period.

$$\begin{aligned}\textbf{lognGDP} =& -\textbf{348.5008} + \textbf{0.3474}^{*}\,\textbf{logn}(\textbf{0.875136597}^{*}\,\textbf{Capital\_Stock}) \\ & + \textbf{46.9874}^{*}\,\textbf{ln}(\textbf{year2})\end{aligned} \tag{6.2}$$

Second, environmental stock is decreased by pollution emission and decreased by environmental improvement activity. Pollution emission (Pollution_Function) is an inevitable byproduct resulting from producing ordinary goods as described in Eq. 6.3.

$$\begin{aligned}\textbf{Pollution\_Function} =& \textbf{44.351} + \textbf{0.0001158}^{*}\,\textbf{GDP} - \textbf{0.0000456}^{*} \\ & \textbf{Environmental\_Technology\_Stock}\end{aligned} \tag{6.3}$$

The variable *Pollution_Function* means composite pollution emission as an aggregate pollution emission of SOx, NOx, and CO_2 computed by PCA. PCA involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. In other words, we attempt to estimate systematically the representative composite pollution emission, not just by simple average but by a scientific method called PCA. Pollution emission also depends on the abatement technology reflected on *Environmental_Technology_Stock*, which can be translated into a certain level of environmental technology advancement or international competitiveness in green goods by accumulating environmental R&D. Since pollution emission is a flow variable and environmental quality index is a stock variable, we need a transformation process *(env_pollution_transform_fcn).* This function

[7] Environmental activity means the whole environment related activities, which includes environmental augmentation *(Env_Augmentation_expenditure),* environmental R&D *(Environmental_R&D)* and capital formation (Capital_formation).

transforms emission quantity flows into environmental concentrations, etc. Coefficients are empirically estimated.[8]

$$\textbf{env\_pollution\_transform\_fcn} = \textbf{exp}(\textbf{8.816566621} - \textbf{0.916511998} \; {}^{*}\textbf{logn}(\textbf{Pollution\_Function})) \tag{6.4}$$

Environmental improvement or augmentation activities (*Env_Augmentation*) increase environmental stock, and *Env_Augmentation* is determined by environmental expenditure as shown in Eq. 6.5 where adj_factor denotes the coefficient links government's expenditure to environmental augmentation.

$$\textbf{Env\_Augmentation} = \textbf{logn}(\textbf{Env\_Aug\_Exp}) \, {}^{*} \, \textbf{adj\_factor} \tag{6.5}$$

Finally, we assume that environmental technology stock is accumulated, not depreciated. Environmental technology development is also assumed to be embodied within the environmental technology stock. Notice that the environmental technology stock may affect the pollution emission function as an exogenous parameter.

6.6 Determining the Environmental Investment Rates Using a System Dynamics Model

To constitute a final Green Growth Index, we first need to find the environmental investment rate with the highest fitness for real data, and then to take this as the weight assigned to environmental service in forming the Green Welfare Index. Next, we search the environmental investment rate to maximize the stream of Green Welfare Indices as explained above.

The weight (or environmental investment rate) with the highest fitness for data is interpreted as the way in which the streams of capital stock and environmental stock generated by the System Dynamics Model most suitably fit the corresponding real data. We will change the weight (or environmental investment rate) a little to calculate the so-called Sum of Squared Error Ratio as defined below in Eq. 6.6, finally searching the most fitting weight. Data_Capital in Eq. 6.6 means actual capital stock.

$$\textbf{sum\_SE\_K} = \boldsymbol{\Sigma}\, \textbf{((Capital\_Stock-Data\_Capital)/Data\_Capital)}^{\textbf{2}} \tag{6.6}$$

[8] For more detail see Han et al. (2009).

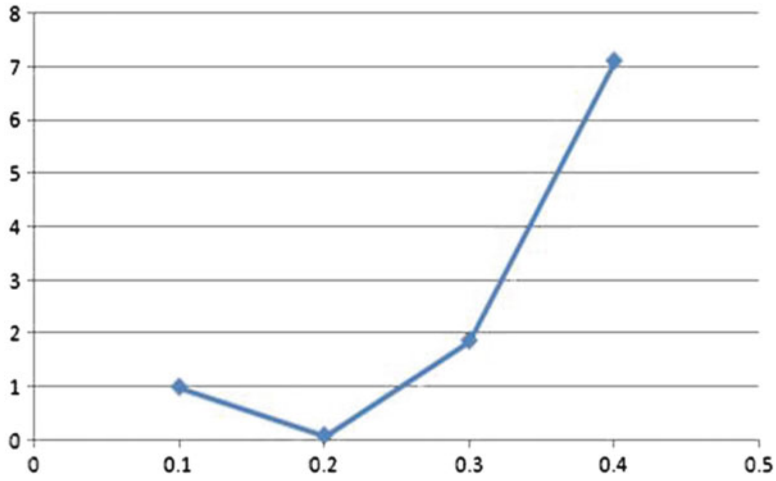

Fig. 6.3 Best fitting environmental investment rate

Table 6.1 Best fitting environmental investment rate

Environmental investment rate	0.1	0.2	0.3	0.4
Degree of fitness	1	0.09	1.87	7.11

We define the so-called Degree of Fitness in Eq. 6.7, incorporating the Sum of Squared Error Ratios of both capital stock and environmental stock.

$$\mathbf{deg\_fitness} = \mathbf{sum\_SE\_E} + \mathbf{sum\_SE\_K} \tag{6.7}$$

where *sum_SE_E* stands for the Sum of Squared Error Ratio for environmental stock.

6.6.1 Searching the Weight with the Highest Degree of Fitness

Figure 6.3 draws the locus of *deg_fitness* by varying the weight (or environmental investment rate) from 0.1 to 0.4. In the diagram, the horizontal axis stands for the weight, whereas the vertical axis represents the degree of fitness. As you can see, the degree of fitness is minimized when the weight is assumed to be 0.2. The exact value for the degree of fitness is shown in Table 6.1. The fact that the degree of fitness takes the highest value when the weight is 0.2 means that the capital stock and environmental stock generated by our model fit the corresponding real data the most at weight 0.2.

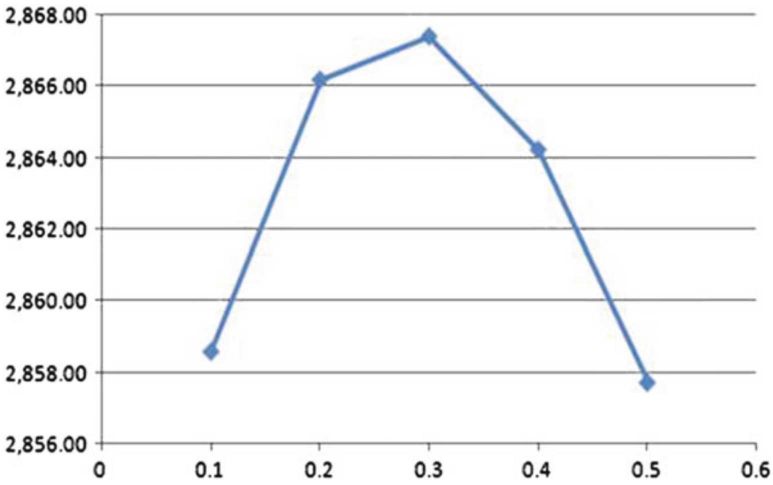

Fig. 6.4 Optimal environmental investment rate

Table 6.2 Optimal environmental investment rate

Environmental investment rate	0.1	0.2	0.3	0.4	0.5
Discounted sum of GWI	2,858.58	2,866.19	2,867.41	2,864.23	2,857.71

6.6.2 Searching the Optimal Environmental Investment Rate

Next, with the weight for constituting the Green Welfare Index fixed at 0.2, i.e., produced the highest degree of fitness, we search the optimal environmental investment rate that maximizes the discounted sum of Green Welfare Indices. In Fig. 6.4, the horizontal axis represents the investment rate allocated or imputed to the environmental sector out of GDP; the vertical axis stands for the discounted sum of Green Welfare Indices as defined in Eq. 6.8.

$$\Sigma\ (GGI\_weight\_2*Env\_Index+(1-GGI\_weight\_2)*consindex)/(discount\_rate)^{year} \tag{6.8}$$

where *GGI_weight_2* represents the environmental investment rate; here, it is fixed at 0.2. *discount_rate* means a discount factor, and we assume it to be 1.02.

As we can see in Fig. 6.4, the discounted sum of Green Welfare Indices attains its local maximum when the environmental investment rate or imputation rate is 0.3. The value at the local maximum is 2,867.41. Table 6.2 shows the value at various environmental investment rates.

Figures 6.5, 6.6, and 6.7 represent the locus of consumption, environmental service, and Green Welfare Index, respectively, which are drawn by varying the environmental investment rate from 0.1 to 0.5. The numbers attached to each locus represent the

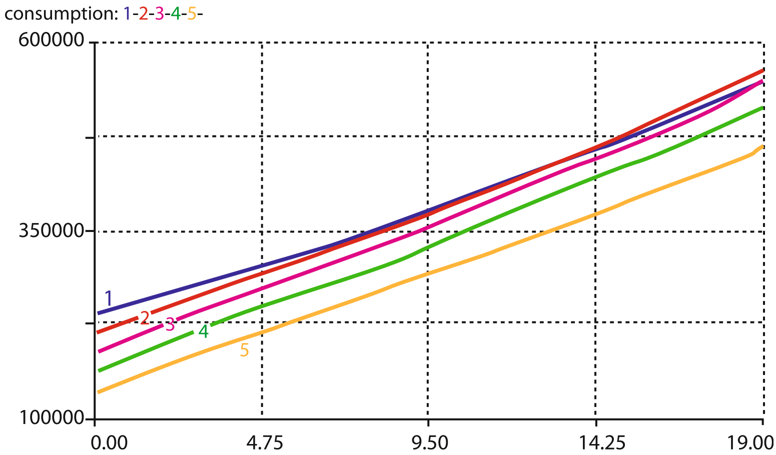

Fig. 6.5 Locus of consumption

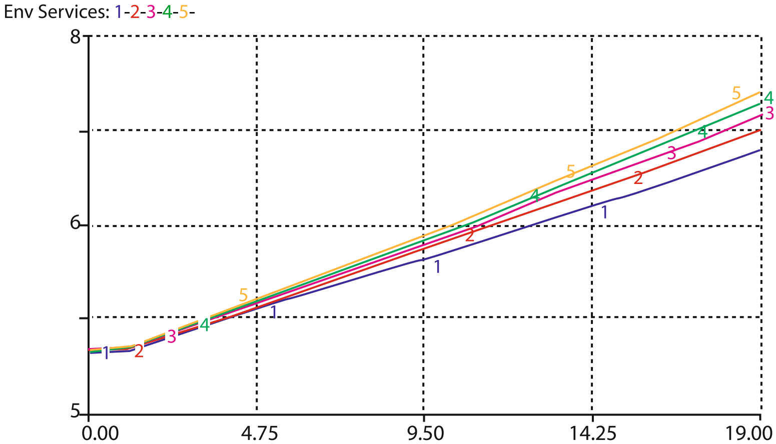

Fig. 6.6 Locus of environmental service

environmental investment rate; 1 represents 0.1, 2 represents 0.2, etc. The levels of these variables differ when the environmental investment rate changes. We are looking for the environmental investment rate which maximizes the discounted present value of GWI. Since the environmental investment rate is the key variable in determining the overall result in the system dynamics model, all variables vary when the environmental investment rate changes. These loci depict how consumption, environmental services, and GWI are evolving over time depending upon the changes in the parameter, environmental investment rate. By examining these loci, we find that there exists a unique environmental investment rate that maximizes the discounted present values of consumption, environmental service, and GWI. The rate that maximizes discounted present value of GWI is found to be 0.3.

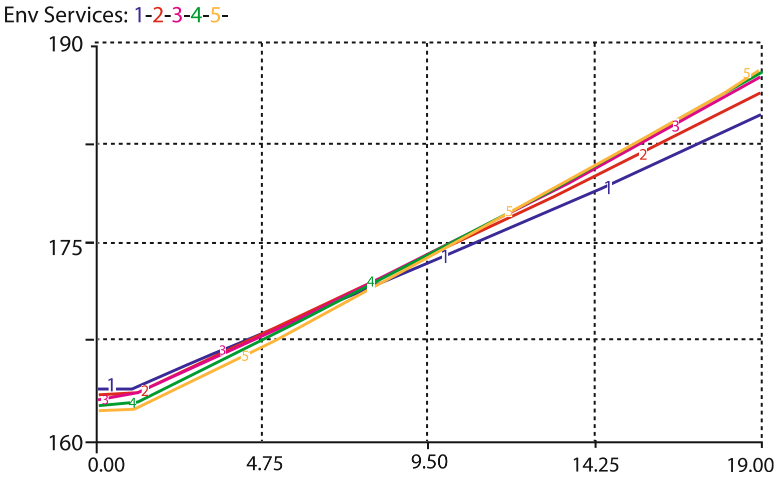

Fig. 6.7 Locus of green welfare index

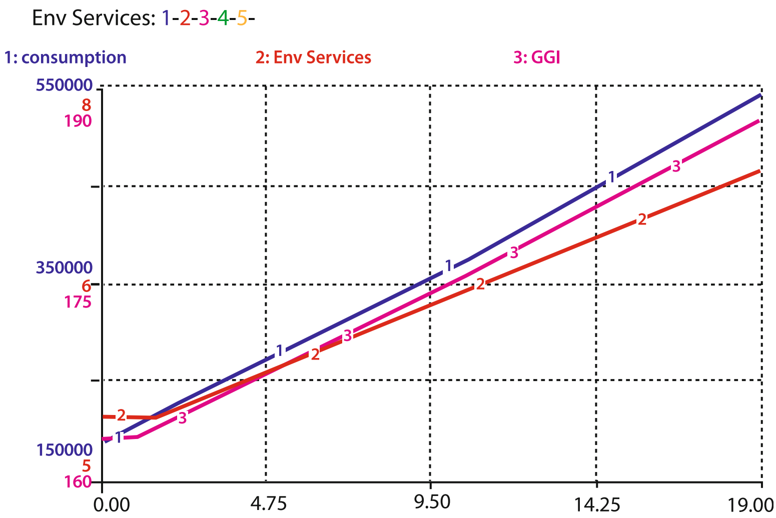

Fig. 6.8 Loci of consumption, environmental service, and GWI

Finally, Fig. 6.8 shows their loci at the optimal environmental investment rate of 0.3. One interesting observation with Fig. 6.4 is that consumption changes abruptly at the turn of 0.4 but remains about the same as the rate varies from 0.1 to 0.3. In Fig. 6.5 we can observe that the environmental service does not change as much as the consumption but increases at a nearly constant rate. These patterns have an implication as to why the discounted sum of the Green Welfare Index culminates in the rate of 0.3. In Fig. 6.6 we observe that as the environmental investment rate increases, the future stream of welfares increases relative to the present stream of welfares. This also gives us a hint as to why the discounted sum of Green Welfare Indices is maximized at the rate of 0.3.

6.6.3 Green Growth Gap and Green Growth Index

As shown above, the optimal environmental investment rate and realized environmental investment rate (best fitted for data) are different. This has an important implication. If the realized rate is smaller than the optimal rate, this implies that environmental investment is not enough. If these two rates are identical, then the economy is in an optimal condition in terms of green growth. Therefore, this difference can be used as a measurement for the degree of deviation of the economy from the optimal green growth path, which we call the 'green growth gap.'

In our dynamic model, w_1 (realized environmental investment rate, w with best degree of fitness) is estimated as 20%, whereas w_* (optimal environmental investment rate, w maximizing the discounted sum of GWIs) is estimated to be 30%. Thus, the green growth gap ($w_2 = 1 - w_1'/w_1*$) is computed as 1 – 20/30 = 33.3%.

By combining the environmental quality index, consumption index, and green dynamic policy index with weights w_1 and w_2 estimated by the system dynamics model, GGIs are computed as shown in Fig. 6.1.

6.7 Computed GGI and Other Indices and Interpretations

The GWI, GDPI, and GGI for the years of 1990–2009 are depicted in Fig. 6.9. Korea's dynamic growth process from 1990 to 2009 did not show optimal growth patterns of economy and the environment. In other words, in terms of environmental policy and regulation and environmental investment, the country and society paid cost less than the dynamically optimal level. Nonetheless, the divergence of realized environmental investment rate from the optimal environmental investment rate was smaller than guessed at first hand. Therefore, the growth path of Korea from 1990 to 2009 is not so bad when assessed from the viewpoint of green growth. The growth rate of GGI compared to the one of GWI is recently accelerated. This is due to the policy and investment on the environment relatively strengthened after the year 2000.

It deserves drawing attention to how much "low carbon" element of green growth is included in these indices. Greenhouse gas mitigation effort of Korean people and government is not directly translated into the environmental services in climate, but it is realized via international community's coordination only. Therefore, the world's representative GHG concentration level, instead of GHG concentration level in Korea, is used as one of the environmental state variables

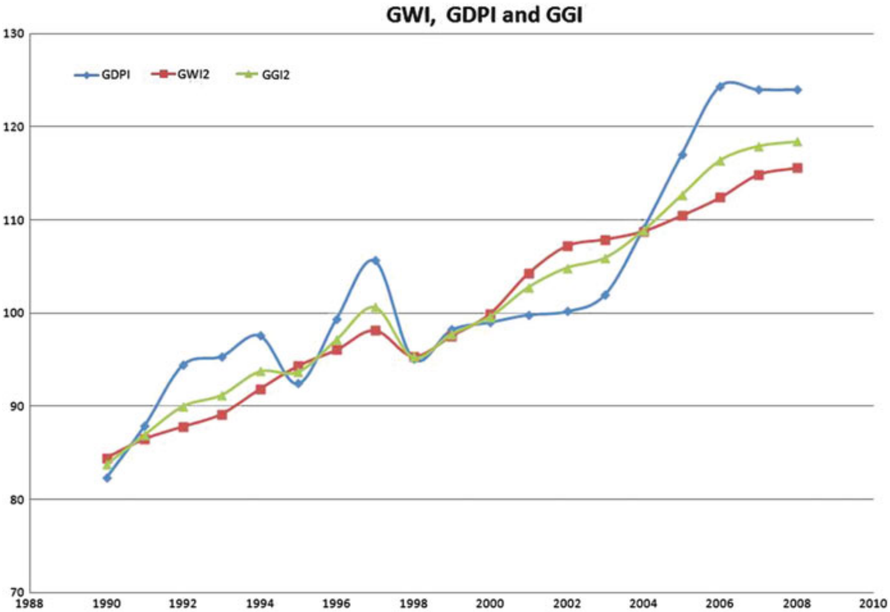

Fig. 6.9 GWI, GDPI and GGI

for Korea. Since Korea has been relatively slow in building institutions[9] to mitigate GHGs, the figures of computed GDPI (Green Dynamic Policy Index) do not have elements for GHG mitigation efforts. In other words, in GDPI, GHG mitigation aspect is omitted because there is no data for institutional effort for GHG mitigation. When these variables are added to the GDPI computation, the level of GDPI and GGI in the past will be lowered, since value for this variable would be considered as zero. Non-institutional efforts for GHG mitigations such as expenditures for GHG mitigation are already included as a part of environmental expenditure as a component of GDPI.

Figure 6.10 depicts annual differences of each index. Looking at differences instead of levels of each index enables us to better analyze the economic and environmental change for each year. By doing so the change in C (consumption – economic index) comes together with the change in P (environmental policy) index. In this case, the magnitude of change in P is larger than in C. Moreover, the change in P precedes the change in the environment (E) index, although this relationship is weak.

[9] "Institutions" may include regulation, emission trading, carbon tax, or national GHG reduction target setting, etc.

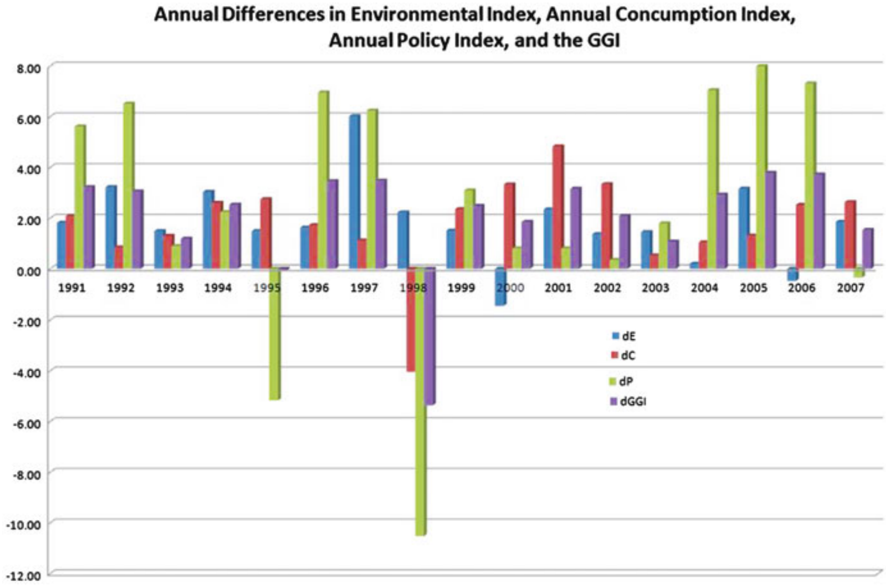

Fig. 6.10 Annual differences in environmental index, annual consumption index, annual policy index, and the GGI

6.8 Conclusions and Policy Implications

The fact that the realized environmental investment rate (0.2) and optimal environmental investment rate (0.3) are different for the Korean economy has important policy implications. This implies that environmental investment in Korea has been lower than optimal – hence the need for more investment in the environment. Since the environmental investment rate is lower than optimal, the current level of green welfare cannot convey correct information on the optimality of the economy. Thus, the weight of the current level of welfare should be reduced in computing the green growth index. More emphasis should be given to investment for the future rather than the enjoyment of the current fruit, particularly with regard to the environment. If the gap widens, this is a signal that investment should be strengthened further.

Although this gap itself is an index and a good policy signal, we need more concrete and digestible one for policy use and public understanding – the Green Growth Index. The Green Growth Index should contain information on the dynamic potential for the future welfare level as well as for the current welfare level. The Index should also work as a policy signal to the government and citizens that the current growth path deviates from the optimal one.

The Green Growth Index may be developed in a wider international context. Still, this seems very hard because of the need to develop a multinational System Dynamics Model, which needs strong assumptions on the parameters for each country and the interrelationships among countries. As a caution with our model from an international perspective, remember that in our model one channel for green growth is the net export of green goods. Note, however, that this implicitly assumes that the country can successfully develop internationally competitive green goods and sell them to other countries. Obviously, this is not always possible. Though it could successfully develop such goods, the country may fail either to develop such green goods or to secure relative competitiveness in those goods. Some countries are destined to fail in this international arena for selling green goods, and some waste of resources – or the 'bursting of the green bubble' – may result from the international perspective.

Appendix: Stella Equations

accu_consmp(t) = accu_consmp(t - dt) + (consmp_flow) * dt
INIT accu_consmp = consmp_flow
INFLOWS:
consmp_flow = consumption/(discount_rate)^year
accu_env_svcs(t) = accu_env_svcs(t - dt) + (flow_env_svcs) * dt
INIT accu_env_svcs = { Place initial value here… }flow_env_svcs
INFLOWS:
flow_env_svcs = Env_Services/(discount_rate)^year
acc_GGI(t) = acc_GGI(t - dt) + (GGI_flow) * dt
INIT acc_GGI = GGI_flow
INFLOWS:
GGI_flow = GGI/(discount_rate)^year
Capital_Stock(t) = Capital_Stock(t - dt) + (capital_formation - depreciation) * dt
INIT Capital_Stock = 389230
INFLOWS:
capital_formation = investment*0.449+Env__Activity-Env_R&D-Env_Aug_Exp +cap_from_env_net_export
OUTFLOWS:
depreciation = Capital_Stock*.1
Environmental_Stock(t) = Environmental_Stock(t - dt) + (aug_flow - pollutionflow) * dt
INIT Environmental_Stock = 82.2426+aug_flow+pollutionflow
INFLOWS:
aug_flow = ((Env_Augmentation-delay(Env_Augmentation,1))^.91)*2.0
OUTFLOWS:
pollutionflow = ((-env_pollution_transform_fcn+delay_env_trans_fcn)^1.3)*0.7
Environmental_Technology_Stock(t) = Environmental_Technology_Stock(t - dt) + (Env_R&D) * dt
INIT Environmental_Technology_Stock = Env_R&D
INFLOWS:

Env_R&D = Env__Activity*R&D_intensity
sum_SE_E(t) = sum_SE_E(t - dt) + (Flow_SE_E) * dt
INIT sum_SE_E = Flow_SE_E
INFLOWS:
Flow_SE_E = SE_of_Env_Stock
sum_SE_K(t) = sum_SE_K(t - dt) + (SE_K_flow) * dt
INIT sum_SE_K = SE_K_flow
INFLOWS:
SE_K_flow = SE_of_Kapital
year(t) = year(t - dt) + (yearadd) * dt
INIT year = 1
INFLOWS:
yearadd = 1
year2(t) = year2(t - dt) + (year1) * dt
INIT year2 = year1+1989
INFLOWS:
year1 = initial_year
adj_factor = 40
cap_from_env_net_export = env_net_export_parameter*Env__Activity
consindex = 100+(consumption-300000)/100000*2 + 100
consumption = GDP-investment-Env__Activity
deg_of_fitness = sum_SE_E+sum_SE_K
delay_env_trans_fcn = DELAY(env_pollution_transform_fcn,1)
discount_rate = 1.02
Econ_Policy = 0.299
Env_Augmentation = logn(Env_Aug_Exp)*adj_factor
Env_Aug_Exp = Env__Activity*0.0037/Env_Policy
Env_Index = 100*(Env_Services-6.5)/4*2+100
env_net_export_parameter = 0.01
Env_Policy = (1-Econ_Policy)*env_weight*env_policy_factors
env_policy_factors = 1
env_pollution_transform_fcn = exp(8.816566621-0.916511998* logn(Pollution_Function))
Env_Services = 0.06*Environmental_Stock
env_weight = GWI_allocration_ratio*1
Env__Activity = GDP*Env_Policy
GDP = exp(-348.5008+0.3474*logn(0.875136597*Capital_Stock)+46.9874*logn(year2))
GGI = GGI_weight_2*Env_Index+(1-GGI_weight_2)*consindex
GGI_weight_2 = 0.3
GWI_allocration_ratio = 0.3
initial_year = 1
investment = GDP*Econ_Policy
Pollution_Function = 44.351+0.0001158*GDP-0.0000456*Environmental_Technology_Stock

R&D_intensity = 0.05
SE_of_Env_Stock = ((Environmental_Stock-Data_Env_Stock)/Data_Env_Stock)^2
SE_of_GDP = GDP-Data_GDP
SE_of_Kapital = ((Capital_Stock-Data_Capital)/Data_Capital)^2
Data_Capital = GRAPH(TIME)
(0.00, 389231), (1.90, 504888), (3.80, 612933), (5.70, 707897), (7.60, 824348), (9.50, 979953), (11.4, 1.1e+006), (13.3, 1.3e+006), (15.2, 1.4e+006), (17.1, 1.5e+006), (19.0, 1.6e+006)
Data_Env_Stock = GRAPH(TIME)
(0.00, 82.5), (1.06, 84.3), (2.11, 86.2), (3.17, 88.1), (4.22, 90.9), (5.28, 93.1), (6.33, 95.5), (7.39, 101), (8.44, 104), (9.50, 106), (10.6, 106), (11.6, 106), (12.7, 107), (13.7, 109), (14.8, 107), (15.8, 111), (16.9, 110), (17.9, 112), (19.0, 111)
Data_GDP = GRAPH(TIME)
(0.00, 186691), (1.06, 226008), (2.11, 257525), (3.17, 290676), (4.22, 340208), (5.28, 398838), (6.33, 448596), (7.39, 491135), (8.44, 484103), (9.50, 529500), (10.6, 603236), (11.6, 651415), (12.7, 720539), (13.7, 767114), (14.8, 826893), (15.8, 865241), (16.9, 908744), (17.9, 975013), (19.0, 1e+006)

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Chapter 7
Environmental Impacts of Korea-Europe Automotive Supply Chains; Moving Towards a More Sustainable Model

Paul Nieuwenhuis, Andrew Ki-Young Choi, and Anthony Beresford

Abstract The question of how growth can be reconciled with sustainability is particularly pertinent in the case of cars. Environmental impacts of vehicle manufacture and use have been widely studied; those of the logistics of new vehicle distribution less so. Japan and Korea together constitute by far the leading source region for shipped cars both in terms of volume and carrier-miles generated. By implication, exported Japanese and Korean vehicles account for substantial amounts of greenhouse gases as they travel; first by ship, then onward by rail or road. Loading and unloading cars under their own power generates additional impacts.

In an apparent reversal of globalization, recent years have witnessed a gradual transfer of production from the home countries of Asian firms – notably Japan and Korea – to locations nearer to recipient markets. However, the environmental implications of such shifts in production location have not been widely considered. Here we are analyzing this process from an environmental perspective.

The research centres on Kia and Hyundai, contrasting the conventional route from Ulsan/Pusan to Western Europe whereby shipping is the principal mode, with the alternative of trucking cars from the new transplant locations in Slovakia and the Czech Republic. The latter is shown to have a significantly lower impact. The results may be surprising, but could have implications for future location

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decisions of car factories and – potentially – other manufacturing facilities, as well as raising wider questions about the long term viability of the globalised car system in favour of some more localized solution.

Keywords Automotive industry • Korea • Japan • Shipping • Carbon dioxide emissions

7.1 Introduction

Nature demands local expertise

(Benyus 1997, 7)

The question of how economic growth can be reconciled with sustainability is particularly pertinent in the case of cars. Generally regarded as one of our least sustainable systems, such that the very notion of the current car system is increasingly being challenged (Dennis and Urry 2009). Yet such analyses often overlook the progress that is being made by elements of the car system, albeit marginal by comparison to what is needed for sustainability. Much of the drive for growth in automobility is in the nature of the technologies chosen for delivering mass production to serve mass markets (Nieuwenhuis and Wells 1997, 2003, 2007). These technologies essentially force mass car producers into doing just that: mass producing cars, with demand often a secondary consideration. As the home markets of mass car producers increasingly reach saturation point, the need to export to keep the manufacturing system working to its optimum or even minimum economies of scale becomes ever more pressing. Where key production facilities are isolated and far from many key export markets – as in the case of Japanese and Korean manufacturers – logistics systems become increasingly complex. Thus such car makers are forced to choose between shipping to such markets or localizing manufacturing to those markets. This chapter assesses the impact in terms of transport CO2 of such strategic choices; an aspect of globalization not studied before in this level of detail.

However, in order to even approach sustainability – if a sustainable car industry is indeed possible – the car system in reality demands much more radical change (Hart 1997). Some recent work suggests adopting something more akin to an ecosystem approach to our economic systems (Field and Conn 2007; Krebs 2008; Nieuwenhuis and Lammgård 2010) and in this context viewing the automotive system in an ecosystem perspective may be productive. The analysis of human systems, be they economies, societies, or human organisations has been dominated by what Field and Conn (2007) refer to as 'linear' and 'mechanistic' approaches. These seem increasingly inadequate in their explanatory power especially in the light of current events and upheavals. A more integrated narrative is needed, and an attempt to explore the ability of ecology, particularly an ecological system analogy, could provide this new explanatory force (Nieuwenhuis 2008; Nieuwenhuis and Lammgård 2010). While some ecologists and biologists have hinted that the ecosystem approach has lessons for human systems, few have attempted to extend their analysis far beyond such assertions. Yet, the ecosystem analogy has considerable explanatory force and may also be easier to communicate to user communities than more conventional academic models. In the present context, Benyus' opening statement that nature favours the local is of particular relevance (Benyus 1997).

Two major areas of concern currently threaten the survival of firms and indeed of entire industrial sectors. On the one hand, the economic crisis forced many firms to reconsider their economic sustainability, prompting moves to an economic survival strategy, such as at General Motors and Chrysler. On the other, the need for firms and sectors to reconsider their compatibility with broader environmental and resource sustainability is becoming more urgent. In no other sector are both these concerns more pertinent than in the automotive industry, which therefore makes for a useful case.

At the same time, this is also a sector that has shown a remarkable resistance to genuine diversity, thereby limiting its resilience and flexibility – including in terms of market responsiveness – since its adoption of the mass production regime between about 1910 and 1940 (Nieuwenhuis and Wells 2007). Yet there are elements of diversity within the current regime that could form the basis of a successful transition process for the sector as a whole, albeit at the expense of some of its – currently – major players, or dominant technologies and systems. The tension between the local needs of markets – akin perhaps to Benyus' notion that nature favours the local – and the centralizing need of the mass production system is a key area of conflict that may find its resolution in options more in harmony with the need for sustainability. In the current system such solutions, where they exist, are marginal and often not apparent, yet as conditions change they may become more prominent (Nieuwenhuis 2008; Nieuwenhuis and Lammgård 2010).

In a future sustainable automotive ecosystem, therefore, alternative business models such as micro factory retailing could emerge as a more prominent form of car supply and use. MFR is based on networks of small dispersed, combined assembly, retail and aftercare (e.g. maintenance and repair, parts supply, upgrade, vehicle management and take-back) facilities. These would supply local markets, sourcing from local suppliers, while being rooted in local economies and in tune with local needs (Wells and Nieuwenhuis 2004a, b; Nieuwenhuis 2008). Although very far removed from current mass car manufacturing practices such as those discussed here, it is significant that mass car manufacturers increasingly see the need to manufacture, or at least assemble, locally for local markets; thereby moving away from the globalised model of supplying global markets with standardized products from centralized manufacturing facilities. In addition to the need to be more in tune with local needs and fluctuations in local demand, the rising cost of transport – driven by the rising cost of fossil fuels – may well drive more such localization in future. The research findings presented in this chapter also suggest a significant advantage in terms of environmental impact from such localization strategies.

7.1.1 Finished Vehicle Logistics

Environmental impacts of both vehicle manufacture (e.g. Nieuwenhuis and Wells 1997, 2003; Van de Sand et al. 2007) and usage (cf. Kendall 2008 and Sperling and Gordon 2009 for recent examples) have been widely discussed. However, the environmental externalities of the logistics of new vehicle distribution have been less widely considered. Japan and Korea are by far the leading source countries for shipped cars both in terms of volume (cars exported per annum) and in terms of carrier-miles generated (Beresford et al. 2002; Automotive News Europe 2008). By implication, exported new Japanese and Korean vehicles may indirectly account for substantial amounts of greenhouse gases as they travel; first by ship, then onward by rail or road. A significant amount of transshipment also takes place in the form of:

- deep sea/short sea involving 'feedering' from lower to higher capacity ships,
- deep sea/inland waterway, for marine-riverine flows,
- transfer from one deep sea vessel to another.

This too has environmental implications. Not insignificant either are the inland transport legs and terminal activities – some of which involve loading and unloading cars under their own power – which clearly generate additional CO2 as well as toxic emissions, albeit within a confined area.

The transport cost model was first developed by Beresford (1999), and provides a convenient framework for tracking the processes and activities in any medium-to-long supply chain identifying activities and costs at different points in the supply chain. However, it is only now beginning to be used to identify and extract the environmental impacts involved in these chains (e.g. Eefsen 2008). In this chapter, environmental data are combined with this transport cost model such that initial estimates of the environmental impact – in terms of CO2 output – of Korea-Europe automotive supply chains may be made. The computation is then compared with the impact of supplying the EU market from local transplant production.

This research makes use of information supplied by Kia and Hyundai and at this stage embraces built-up vehicle flows. This can then be expanded firstly to include containerized kits (CKD/SKD[1]) and components shipments to the transplants in Central Europe and Turkey, and perhaps to the overall generic question of the impacts of close-to-market versus least-cost production location (Lee et al. 2006).

[1] When not fully assembled locally, cars are shipped in kits for near-market assembly in two forms: CKD – completely knocked down kit, which involves the assembly facility in full assembly, including – usually painting. With SKD – semi-knocked down kits the body is often painted and partly trimmed, allowing a lower cost assembly facility to be used viable at lower volumes.

Table 7.1 Korean sales in Western Europe 2008 and 2009

Make	Sales 2008	Market share	Sales 2009	Market share
Daewoo-Chevrolet	146,514	1.1	169,128	1.2
Hyundai	227,370	1.7	301,330	2.2
Kia	194,890	1.4	218,917	1.6

Source: AID (2010)

7.1.2 Background

Much of Japanese close-to-market production is now in place through their transplant facilities in Europe and North America. In the early twenty-first century Japanese manufacturers started expanding with new capacity in Eastern Europe and China (Nikkei Weekly 2006). For South Korean car makers, this transplanting trend is more recent and in the case of Europe, in reality is only just beginning (Kia 2006). Although the recession slowed down such ventures throughout the automotive sector, Korean manufacturers were less affected than some, benefiting in particular from the various scrappage schemes introduced in Europe to help combat the recession (AID 2009a; Table 7.1). Unlike most domestic manufacturers, all three Korean car manufacturers managed to increase sales in both 2008 and 2009, the years when the recession was at its deepest (AID 2009a).

Having seen their European sales and market shares rise in recent years, much of this rise in Eastern Europe, Korean manufacturers have been building European plants to localise production (Phillips 2006). Between 2001 and 2005, Korean manufacturers more than doubled their sales in Europe, while Russia has also become a major recipient of Korean products, welcoming new and used imports as well as locally assembled Korean cars. Chevrolet-Daewoo's Nexia and Hyundai's Accent were among the top five sellers in Russia in 2005 and 2006 (Stein and Smolchenko 2006; Smolchenko 2007).

With the new Hyundai and Kia facilities in central Europe, the proportion of vehicles produced locally has increased further. Pre-recession forecasts indicated that combined Hyundai and Kia production would reach over 600,000 units annually by 2010 (Power 2005). These figures also include production in Russia where GM has opened a Chevrolet assembly facility. There is existing production in the region by Chevrolet-Daewoo via ZAZ[2] in Ukraine. Kia has a plant in Slovakia, while Hyundai has opened a facility in Nošovice in the Czech Republic. These developments also have environmental implications, of course, though quantifying the CO2 changes derived from production shifts on a global scale is difficult, if not impossible, to achieve with any certainty. However, one can assume that while additional facilities are likely to add to overall impact, more modern facilities tend to have a lower impact than older plants of similar capacity as they are normally built to higher standards in terms of energy consumption and pollution control,

[2] Zaporizhzia Automobile Building Plant: the biggest car manufacturer in Ukraine.

at least in the global automotive industry and when operating in locations such as the European Union.

While the capacity is now in place to meet the forecast figures, the actual volumes are lagging behind slightly as a result of the recession. In 2008, Korean production amounted to some 3.8 million units, of which 2.7 million were exported; 0.7 million to Europe (AID 2009a, b). However, both Kia's facility in Zilina and Hyundai's in Nošovice are increasingly contributing to the total with an installed capacity of 300,000 vehicles annually at each facility. In 2009 this facility produced just over 150,000 vehicles; a decline from 2008 (201,507) and 2007 (159,116), due primarily to the collapse of the Russian market, which in 2009 still took 21% of production (KMS 2009). Zilina produces the Cee'd, Cee'd_sw estate model, Pro_cee'd and Sportage SUV. In addition, in 2010 it added the new Sportage and its sibling, the Hyundai ix35, which replaced the Tucson SUV. Hyundai's Czech plant at Nošovice produces the i30, i30 cw estate and the Kia Venga. The plants are closely integrated, with each not only producing models of both brands, but Zilina supplying engines to Nošovice, which in turn supplies transmissions to Zilina (www.hyundai-motor.cz). One of the key beneficiaries of European scrappage incentives was the Hyundai i20, which was sourced from Chennai in India. However, this model's European market version has been built at Izmit in Turkey since May 2010 (HMMC 2010a).

In broad terms, the likely effect of this transplanting on shipped volumes from Korea is clear. Any Korean car sold in Europe that is built in Europe is not shipped from Korea. With Korean production capacity in Europe at a level close to half typical European market demand, new car shipping volumes from Korea to Europe will be much reduced. On the other hand, inland shipping of cars along the Danube and Rhine is likely to show further growth; there are already early signs of this trend, due in part to increased pressure on land and rail-based car transport capacity (Ricciuti 2006, 2007). In the longer term, shipping to Vladivostok and rail into more western regions of Russia may also become a significant route, building on the established container land bridge which has been offering Far East – Europe services for a number of years (ESCAP 2006).

7.1.3 Environmental Impact

Given the clear strategy among Korean car manufacturers to move away from shipping built-up units from Korea and towards a model of local EU assembly and full production, the question arises whether this shift has any significant environmental implications. In order to assess this we will focus our analysis on emissions of carbon dioxide during the logistics phase, i.e. from the end of the production line/factory gate to the dealer, or at least to a regional distribution hub. There are various environmental impacts of shipping, many linked with the high-sulphur bunker fuel being used, though in view of current concerns regarding issues such as climate change and resource depletion we have opted for CO2 as a measure of environmental performance (Olivier and Peters 1999; Fet 2003). This also allows a comparison to be made between different transport modes encompassing both sea and land based modes in this case, as CO2 figures for different modes are either readily available, or can reasonably easily be calculated. Whilst there are clearly other metrics that could be used, this approach should provide an initial indication of the CO2 impact from different manufacturing and distribution strategy models. In both cases, the cost model approach first proposed in Beresford (1999) and later developed in ESCAP (2003) and Beresford et al. (2006a) is used. The analysis here is focused on Hyundai-Kia. This Korean group currently uses a number of different logistics models.

7.2 Methodology

In terms of methodology we have taken as a foundation a combination of existing literature on the car shipping and logistics industry, as exemplified in, for example, Beresford et al. (2002), Wells and Nieuwenhuis (2005), Beresford et al. (2006b). In addition, a series of semi-structured interviews was carried out during calendar year 2009 in South Korea and Europe with Hyundai-Kia and some of their logistics providers.

7.2.1 Assumptions and Limitations

The present analysis is limited to built up units and two alternative exemplar routes have been selected. The first is a conventional route involving cars built at Hyundai's principal assembly plant at Ulsan in South Korea, then trucked to the nearby port of Busan as outlined in Table 7.1. Truck logistics are provided by a number of operators in Korea. The fieldwork in Korea indicates that DongBu Express takes responsibility for built up units from Ulsan although shipping of cars actually takes place direct from Ulsan. Busan Port only provides car shipping facilities for one other car manufacturer. However, distance figures from Busan are more readily available, allowing a wider range of data sources to be used; Ulsan is essentially owned by Hyundai, being also the location of its principal shipyard. Some kits do tend to be shipped via the container port at Busan. In these cases, Daekjung carries out transport of CKD kits from Jeonju to Busan, while Hyundai Logistics handles transport from Asan to Gwangyang by rail and truck. Built-up units are shipped to Europe by car carriers. Such ships are known as Pure Car and Truck Carriers (PCTC) in that they are dedicated vessels for carrying road vehicles that can be loaded under their own power. Movable decks then allow some areas to accommodate taller vehicles, such as trucks, while the majority of deck space in the hold of these box-like vessels, has lower operating height to allow the maximum number of cars to be carried. In this case, most of the PCTCs used are operated by

EUKOR which incorporates the former vehicle shipping division of Hyundai Merchant Marine (HMM), while CKD kits are containerised and shipped by CMA using conventional container ships carrying mixed container loads.

So, although not actually used for this route, in our assumptions, from Busan, South Korea's biggest unit load port, the cars are shipped to north-west Europe, where Rotterdam has been taken as a single location to represent the ports actually used, which tend to be Antwerp, Hamburg and Thamesport. The ship is typically at sea for 31 days, a figure used as the basis for the calculations here, and during its journey the vessel covers 11,067 nm (derived from Aldworth 2007).

The alternative route involves similar vehicles produced at Kia's Slovak plant in Žilina, and trucked to Rotterdam, a distance of almost exactly 1,000 km. Although shipping along the Danube is beginning to be used, at present trucks are the preferred mode in most cases. From there a truck takes the cars in batches of 12 – the typical load for a European car transporter – to a distribution centre, which is assumed to be 100 km away, locating it within the Benelux countries, where many such centres are based.

7.3 Environmental Impact in CO2 Terms

The calculations of the CO2 emissions of the different transport options are based on a number of assumptions. For the truck legs we have assumed – verified from consultation with industry figures in our semi-structured interviews – that a typical 12-car transporter operates at an average fuel consumption of around 1 L every 3 km. However, it should be noted that due to the generally lower gross vehicle weight (GVW) of the equivalent South Korean car transporters, which tend to be derived from Japanese truck designs, they normally take seven or eight cars depending on the model mix on the truck, whereby SUVs clearly take up more space on the transporter than, for example, a small hatchback such as the Hyundai i30. European car transporters are generally derived from higher GVW European trucks and, by contrast, typically take 12 cars. This makes them more efficient in terms of energy used per vehicle carried – which would be reflected in CO2 emissions – while they also tend to have more efficient engine technology giving them a higher specific output with lower fuel consumption. However, as the Korean trucks are lighter, though less efficient overall, these factors have been averaged out and the same fuel consumption figures were used for all car transporters at each end of the supply chain.

Precise figures for CO2 emissions per litre of fuel burnt vary slightly from one source to another. For the present calculation, a single source had to be selected and for this purpose the figures proposed by Moles et al. (2006) have been used. These authors suggest that the CO2 emissions from a litre of diesel fuel are 2,680 g/km. Based on this, the truck emits around 890 g/km. Within Korea, the truck distances from Hyundai-Kia factories to the relevant ports, are set out in Appendix 1. For the emissions of the cars themselves CO2 emissions of 164 g/km have been assumed, which was a typical average figure for a Korean car or Sport Utility Vehicle (SUV) in 2007 (T&E 2007). In addition it has also been assumed that the distance covered for each car-leg of the route amounts to 1 km. These involve the legs from the end of the vehicle assembly line to a holding area, from there into the PCTC or truck and from these sea or road carriers back into a holding area and back onto a truck. In reality, distances may be longer or shorter. At Ulsan, for example, the main assembly facility is located adjacent to the berth for the PCTC and for vehicles shipped directly from there, the distance of 1 km is probably about right. This process also usually involves cold start and cold running, which would significantly increase CO2 emissions to probably nearer 200 g/km.

For the shipping leg, there are a number of issues. As outlined earlier, the vessels used are PCTC, which are equipped with variable height deck sections to cater for a mix of vehicle types in their load. With a cargo of purely passenger cars, decks can remain at the same height throughout. However, when carrying a mixed load including trucks and, for example, earth moving equipment or cranes, sections of some of the decks can be moved up or down to accommodate these taller vehicles. This arrangement, though adding cost, also adds considerable flexibility in terms of the nature of vehicle mixes that can be carried. There is a discernable trend amongst the vehicle shipping companies towards PCTCs, not least in order to comfortably accommodate the growing numbers of larger vehicles such as pick-up trucks and SUVs. These require decks at least 2 m apart in a context where the typical deck height for a car-only vessel is 1.8 m. It should be noted at this point that most of the car production that has been localized to the European Union involves cars, which would suggest that the mix of vehicles being shipped has shifted somewhat towards larger, more luxurious and higher value cars and SUVs.

The current PCTC vessels are of varying ages and sizes, and the fuel can also be of variable quality and generally of a higher sulphur content than diesel, although Olivier and Peters (1999) argue that in CO2 terms, marine bunker fuel is comparable to diesel fuel. As an indication of the age range of ships, the PCTCs in the WalleniusWilhelmsen (WWL) fleet, range from vessels first entered into service in 1977 (2 vessels) to ones that entered into service as recently as 2008 (www.2wglobal.com). However, figures for a specific ship running on this route have been difficult to find. For this reason, we have adopted the figures used by McBride and Sisson (2009). McBride and Sisson (2009) propose a CO2 output for container ships of 650–700 g/kWh. A PCTC is in many respects comparable to a medium-size container ship. When fully loaded, a container ship presents a similar profile to a PCTC, for example, although in view of its cargo, the latter carries mainly air, something that may not be true for a container ship which carries containers with variable contents, but mostly probably of higher density than cars.

For the PCTC, we have therefore taken the lower figure and combined this with the power output of a state-of-the-art PCTC, the Courageous Ace. This vessel is now in service with MOL (Mitsui Overseas Lines), and its engines are rated at 14,160 kW (www.ship-technology.com/projects/courageous_ace). This provides a figure of 9.204 tonnes of CO2/h, which, when multiplied by the number of days (31) of 24 h each, assuming continuous running – a fair assumption – gives a total emissions figure for the journey of 6,847,776 kg of CO2, which, divided by the 6,000 cars carried, gives 1,140 kg/car.

Significantly, Appendix 1 clearly shows that the local transplant option delivers markedly lower overall CO2 emissions. When measured in gram per kilometer per car carried, the PCTC at 55.5 g/km/car has lower emissions than the truck at 74 g/km/car; however, it is the very long total distance covered by the ship – 11,067 nm (20,496 km) from Busan to Rotterdam – that puts it at a disadvantage against the truck which only comes from central Europe to the exemplar Benelux destination.

7.4 Applying CO2 to the Cost Model

The Beresford cost model was developed in the 1990s and first formally published in Beresford (1999). It allows the differential costs of different modes used during the transport phases of a multimodal supply chain to be measured and compared in order for the optimal modal and routing choices to be made on the basis of cost. First used for a UK-Greece case study, it has since been developed further and been applied to other routes (e.g. Beresford et al. 2006a, b). The essentials of the model are that transport, or movement, appears as a progress line whose angle of slope depends on the rate of accumulation of cost with distance. Cargo transfer, e.g. at port, appears as a vertical step in the line (note: when adapting the model to CO2 emissions, such vertical steps are absent, as all movement has a CO2 impact). More recently some tentative moves have been made to adapt it to measuring environmental impacts of multimodal supply chains (e.g. Eefsen 2008; Roussos 2009). Here it is applied to the Korean cars case (Figs. 7.1 and 7.2). The model

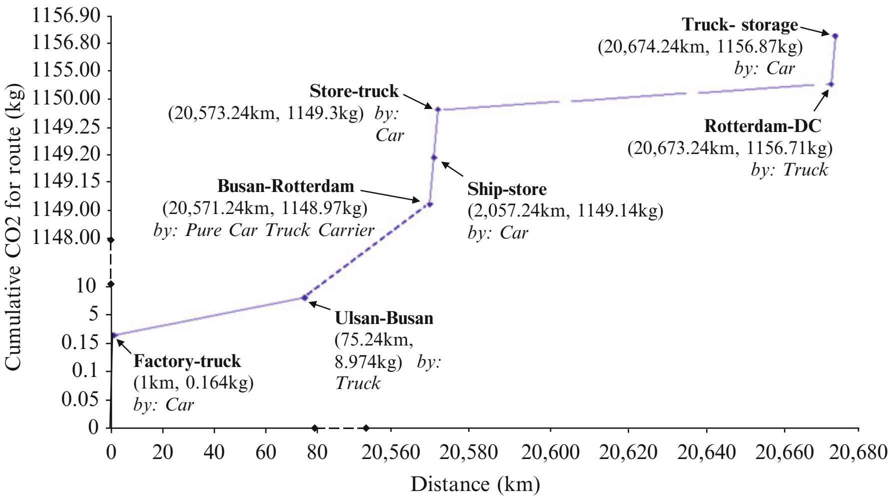

Fig. 7.1 Route 1: ROK – EU

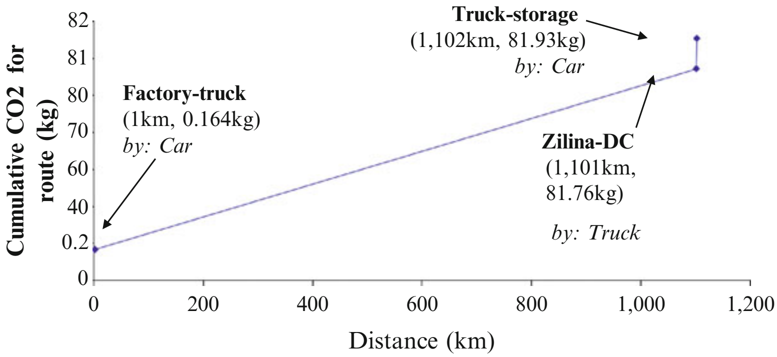

Fig. 7.2 Route 2: EU-EU

essentially shows lines representing phases in a multi-modal logistics chain, whereby the Y axis represents cost and the X-axis distance. Therefore the steepness of the line in the original represents the cost per kilometer – the steeper the higher the cost per km. In the present version, cost is replaced by CO2 emissions, therefore the steeper the line, the higher the emissions per kilometer.

The ultra-low unit cost of modern shipping has been widely discussed (Stopford 2009) and has thus been largely acknowledged as one of the key catalysts for globalization (Leinback and Capineri 2007). For high value cargo such as manufactured goods, of which cars are a classic type, shipping costs commonly represent only 1–5% of retail value, depending on distance between point of manufacture and market, cost at point of sale and other factors. Efficient logistics, especially cheap shipping, thus contribute critically to the footloose nature of much of the world's manufacturing, particularly where logistics follow the normally preferred 'sea maximizing, land minimizing' transport model (Banomyong and Beresford 2001). All previous studies of this type, however, have taken only commercial costs into consideration as hitherto these have driven the manufacturing-logistics systems and hence have biased locational models towards 'least-cost for manufacture' rather 'least cost for the environment' solutions (Dicken 2007).

Similarly, the cost-based approach taken by Beresford (1999) would suggest that, for long supply chains, a 'sea maximizing/land minimizing' approach is consistent with the modern least cost manufacturing business models. Our analysis here clearly suggests that, at least for the supply of cars to European markets by Asian manufacturers, in order to remove CO_2 emissions from the supply chain, a 'sea minimizing/land maximizing' approach may be the most sensible route to follow, at least in the context of European transplant production. We have shown that the difference in environmental impact between localized vehicle production and the production remote from markets is substantial, not marginal. Only if the manufacturing processes themselves were to differ markedly, thus

Table 7.2 Production by model at Hyundai Nošovice, 2009

Model	Units built 2009
Hyundai i30	86,935
Hyundai i30 cw	24,999
Kia Venga	6,088
Total	**118,022**

Source: HMMC (2010b)

somehow generating large CO_2 savings, could the environmental performance gap be narrowed or closed. An additional point is that modern trucks with their comprehensive toxic emissions control technologies, are cleaner per unit of fuel burnt than ships, which have not yet been subject to similar advances in emissions control technology.

Conceivably this environmental gap could be closed somewhat when ships are subject to similar emissions controls as trucks and if, for instance, components were sourced locally over several tiers in the case of the Korea-assembled vehicles. Such a comparison lies well outside the scope of this chapter and would clearly require substantial additional research. We should add that the Korean transplant facilities in Central Europe are modern, efficient, state-of-the-art facilities and thus likely to outperform the now aging Korean plants in terms of CO2 emissions, though, again this has not been specifically investigated. In reality, we can be confident that wherever vehicles are manufactured, the overall nature of the supply base remains roughly the same, as do the processes themselves. The manufacture of export vehicles in the Far East, followed by large-scale shipment of the built up units will inevitably generate a much larger CO_2 footprint than close-to-market manufacturing, whatever the transport mode.

A series of empirical case studies, using the cost model as a framework, suggest that the proportion of total logistics costs which are applicable to movement (inland road/rail haul, feeder shipping and deep sea shipping) is around 80%. This implies that 20% of costs are incurred in initial loading, inter-modal transfer, port handling charges and final unloading, i.e. necessary activities that involve no material progress and add no value along the supply chain. Applying the same principle to CO_2 emissions along our alternative routes detailed in Table 7.2, it appears that inter-modal repositioning of cars in our example of high-volume trade accounts for extremely low proportions of total emissions per car: around 0.33 kg of the 1,155 kg of CO_2. This may understate the proportion of CO_2 attributable to inter-modal handling a little, as the vehicles will not be warmed-up over such short (1 km) cycles; we can be confident, however, that inter-modal transfer of a shipload of 6,000 units is insignificant in terms of its CO_2 burden: around 0.03% of total supply chain emissions. In the case of local manufacture, close to market, short-distance vehicle maneuvering is clearly a higher proportion of the total impact, yet even here it only seems to account for approximately 0.4% of total supply chain CO_2: i.e. still a very small proportion.

For operators weighing environmental impacts against costs, the decision-making process will therefore become more complex in future. We should add to this the increasingly volatile price of oil; a situation that is likely to get worse. Margins in the automotive industry are already relatively small (Nieuwenhuis and Wells 2003). Within this context, adding significantly more costs to both internal and external logistics through a rise in transport costs will lead to serious problems. The ability of the industry to pass such costs on to the customer is very limited. Suppliers themselves have generally even less flexibility than the car assemblers. One way of addressing the problem therefore is to reduce the cost of transport by reducing the need for transport. This can be done by moving fewer goods and by moving them over shorter distances. This could then form a driver towards a more compact logistics network. More compact in that supplies would be sourced from within a smaller area nearer the point of assembly, but also in that supplies of finished goods would cover a smaller area.

7.5 Conclusions

It is clear that the stable, established flows of new cars from Asia to Europe and North America are declining as production is localised in these recipient markets. We have seen this trend for Japanese car exports and it is clear that the same is now happening for the Korean manufacturers. Instead, much more complex flows of new cars will emerge with smaller shipments from car-producing emerging markets such as China to recipient emerging markets, combining with shorter routes from established manufacturing locations – notably Japan and South Korea – to such emerging markets, particularly in Asia. Here shipping is likely to be the lowest environmental impact mode, as distances are shorter and, in much of Asia, land-based alternatives are often unavailable or inefficient due to inadequate infrastructures, distances, congestion, or political limitations (e.g. inability to trans-ship via North Korea).

Over the next decade or so, a fresh flow of new vehicles may also emerge from China and India to serve more mature world markets with cheaper cars assembled at low-cost plants. Chinese manufacturers have ambitions to export to Europe and North America, but – despite some low volume exports to countries such as Italy – as yet their quality and safety do not always match regulations, or indeed expectations in these mature markets (Webb 2006; Bursa 2007). Today the main purpose of such exports is enhanced credibility with consumers in the Chinese home market. This is likely to be overcome by about 2015 when flows of cheaper Chinese cars could start moving around the world. However, as such markets develop beyond a demand for basic automobility and begin to expect greater differentiation tuned to local needs, while at the same time the costs of operating such supply chains becomes a real cost to the business, such distant supply strategies will come increasingly under pressure. In time therefore these will be replaced by local manufacturing nearer to recipient markets. Thus there could well be a decline in global new vehicle shipping volumes as Japanese, Korean and ultimately Chinese production, is localised in recipient markets.

In terms of CO2 emissions this is likely to have a significant beneficial effect, as our findings, outlined above, clearly indicate. The adaptation of the cost tool to handle both cost and CO2 emissions will enable operators in future to make a more informed decision about their manufacturing and logistics options. In the meantime, vessel operators could consider reducing speed in order to cut CO2 emissions. This has been shown to have considerable potential (Kristensen 2007; Eefsen 2008) and this may also be a way of managing supply and demand in the short to medium term, as cars at sea essentially represent stock.

It is clear then, that even within the current, unsustainable, car system, a strategy of localized production building products benefiting from global IPR and R&D efforts can lead to significant savings in terms of CO2 emissions, while at the same time allowing for a globalised system of supply and demand. Although the impacts of such moves are small in the overall scheme of things, the cumulative effect of such decisions will be beneficial, while at the same time raising expectations in local markets of local assembly. More important, perhaps, is the fact that it encourages the industry to think in terms of enhanced sustainability and greater sensitivity to local needs, a mindset that can then be applied in due course to the business at a more fundamental level, leading perhaps to an industry capable of delivering personalized motorized transport solutions that are genuinely sustainable, while allowing at the same time economic growth. Alternatively, it may point the way to a more radical development involving a more localized model for delivering many such products and services. A number of factors currently act together to build pressure for change away from the global and towards the local, despite the fact that in recent years ever more efficient shipping has been pulling in the opposite direction. These drivers for change include a grass-roots reconsideration of the benefits of globalisation in many of its manifestations. In its stead a return to the local is being proposed by a number of commentators (Schumacher 1973; Wells and Nieuwenhuis 2004a, b), although this has not yet fully captured the public imagination everywhere. Looking at industrial activity we find that its current shape is largely determined by factors in the past that no longer prevail in much of the world today.

The car industry is ready for some dramatic technology changes in both products and production methods and the first signs of this change are visible today. Most notable among these is the drive towards electric powertrain, which will also prompt a rethink on the way cars are built and delivered – the business model. These changes could make the current structure of the industry consisting of large centralised assembly facilities, sourcing and supplying globally, largely redundant. In this context, the localization moves of Korean manufacturers may well prove to be more significant than they appear to be at present.

Appendix 1

CO2 Emissions for two typical routes

	Distance (units)	Mode	CO2/unit (g/km)	CO2 for route	Cars/ load	Nr of loads	CO2 per car (kg)
Route 1 ROK-EU							
Factory-truck	1 km	Car	164	164 g	1	6,000	0.164
Ulsan-Busan	74.24 km	Truck	890	66 kg	7.5	500	8.81
Busan-Rotterdam	31 days/744h/ 20,496 km	PCTC	650 g/kWh	6,847,776 kg	6,000	1	1,140
Ship-store	1 km	Car	164	164 g	1	6,000	0.164
Store-truck	1 km	Car	164	164 g	1	6,000	0.164
Rotterdam-DC	100 km	Truck	890	89 kg	12	500	7.41
Truck-storage	1 km	Car	164	164 g	1	6,000	0.164
Total							**1156.88**
Route 2 EU-EU							
Factory-truck	1 km	Car	164	164 g	1	6,000	0.164
Zilina-DC	1,100 km	Truck	890	979 kg	12	500	81.6
Truck-storage	1 km	Car	164	164 g	1	6,000	0.164
Total							**81.93**

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Chapter 8
Strategic Responses of Multinational Corporations to Environmental Protection in Emerging Economies: The Case of the Petroleum and Chemical Sectors in Latin America and the Greater China Region*

Titus Fossgard-Moser, Terence Tsai, and Yuan Lu

Abstract This article examines the responses of multinational corporations (MNCs) to environmental protection issues in emerging economies in Latin America (the petroleum industry in Colombia and Peru) and Greater China (the chemical sector in Mainland China and Taiwan). MNCs play an increasingly important role in the sustainable development of emerging economies as more and more developing countries begin to adopt green growth policies. This paper shows how the liability of foreignness imposed by local institutions on MNCs influences them to be more responsive to environmental protection issues than other types of companies. At the same time the paper shows that while the environmental responsiveness of MNCs is largely driven by the local operational context (in particular, legislative demands), when MNCs see good environmental performance as a source of

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potential competitive advantage in a host country's market, they are more prone to draw upon resources, environmental capabilities, and experiences based upon their global policies and practices. Within this context and provided the right external institutional and internal corporate contexts MNC subsidiaries play an important role in Green Growth of developing countries.

Keywords Green Growth • Environmental Ethics • Environmental Management • Multinational Corporations • Emerging Economies • Local Context

8.1 Introduction

The role of Multinational Corporations (MNCs)[1] in the economic development of emerging economies is an increasingly important scholarly and managerial topic (Hoskisson et al. 2000; UNCTAD 2000; Wright et al. 2005). This is accompanied by recent growth in research focusing on the issues of Corporate Social Responsibility (CSR) and the role of MNCs in the advancement of global ecological ethics (Andersson et al. 2005; Hunter and Bansal. 2007; Yu and Lin 2008).

It is commonly accepted that emerging economies are different from advanced market economies in the aspects of political, economic, and social institutions (Meyer and Rowan 1977; DiMaggio and Powell 1983, 1991; Zucker 1987; Meyer and Scott 1983; Oliver 1997). When MNCs enter emerging economies, they are confronted with two opposing forces. The first is regulatory control imposed by the local environment. Yu and Lin (2008)'s study found that there is local responsiveness pressure for MNC subsidiaries, and a positive relationship exists between the level of green management and the level of local institutional pressure. In addition, Scholars in the study of foreign direct investment (FDI) argue that MNC's foreign nationality can become a liability particularly when local institutions, including governments, non-government organizations (NGOs), and societies in a given country, use it as a lever to achieve other objectives (e.g. introducing tougher legislation, lobbying against FDI etc.). The process through which a MNC is adaptive to the requirements of local institutions is termed 'localization'. The other force

[1] In this article a multinational corporation is defined as a foreign enterprise (a) comprising entities in two or more countries, (b) which operates under a system of decision making permitting coherent policies and strategies on environmental issues through one or more decision making centers and (c) in which entities are so linked that one or more of them may be able to exercise a significant influence over the activities of the others, and in particular to share knowledge, resources and responsibilities with others. Overseas independent companies are defined as foreign enterprises (a) comprising entities operating in up to a maximum of four countries, (b) but within which there is no or only a limited system for coherent decision making on policies and strategies on environmental issues throughout the organization and (c) within which individual entities are unable to exert significant influence over the activities of others. The category local company comprises both state owned enterprises, or enterprises that are owned by the national government of the country within which the enterprise operates and any privately owned local enterprise whose headquarters are located in the country of investigation.

stems from internal standardization within MNCs (Rosenzweig and Singh 1991; Westney 1993). This concerns the consistency of internal operating procedures and practices among subsidiaries of a MNC. The process through which MNCs use internal standards, policies and procedures to manage subsidiaries is termed standardization. Recent studies have also paid attention to the internal standardization process of enacting ecological sustainability in MNCs (Blau and Andersson 2005; Hunter and Bansal 2007).

It is in relation to the debate concerning MNC localization versus standardization, that this study examines two important questions relating to the responses of MNC subsidiaries to environmental protection pressures in two emerging economic regions: Latin America (Colombia and Peru) and Greater China (Mainland and Taiwan):

- What are the responses of MNC subsidiaries to the liability of foreignness in a given country? This question concerns the differences in environmental performance between subsidiaries of MNCs and local firms in a given country under the requirements of local environmental protection policies.
- Do MNCs (through their subsidiary operations) apply uniform environmental practices world-wide or differentiate practices across countries? This question concerns whether MNCs apply standardised global practices or there are variations according to the local context.

MNCs in the petroleum and chemical industries are used as case studies to investigate the two research questions. The industries considered are two of the most important in the world, and it is within emerging economies that MNCs are expanding most aggressively. Evidence of the growing importance of Latin America and Greater China is highlighted by record levels of FDI—$90 and $66 billion, respectively, in 1999 (UNCTAD 2000, pp. xvii, xviii, 49–57, 57–63). Further, both industries have faced recent criticism for their environmental impacts, particularly in emerging economies.

FDI inflows to South, East and South-East Asia, and Oceania maintained their upward trend in 2007, reaching a new high of $248 billion, an increase of 18% over 2006. At the sub-regional level, China and Hong Kong remained the two largest FDI destinations in the region. FDI inflows into Latin America and the Caribbean increased by 36%, to a record level of $126 billion (UNCTAD 2008).

8.2 Theoretical Background and Framework

8.2.1 Green Growth Policies in Greater China and Latin America

8.2.1.1 The Green-Growth Policy in China

China, the world's biggest polluter, plans to "go green" in the next 5 years, emphasising energy efficiency and a war on its choking pollution in its plans to revamp the economy. The so-called 12th five-year plan is expected to be reviewed and rubber-stamped by delegates to the National People's Congress. Beijing has already launched an ambitious programme to develop clean energy and shut down factories that fail to meet emission targets. It also wants to reduce its energy consumption per unit of GDP, or carbon intensity, by 40–45% by 2020, based on 2005 levels—essentially a vow of greater energy efficiency, but not an absolute cap on emissions. The government also wants to step up its fight against pollution, which is threatening the health of China's 1.34 billion people on a daily basis, after 30 years of rapid industrialization.[2]

8.2.1.2 Taiwan

Taiwan is playing its part in APEC's drive to promote more efficient energy use and slow global warming. The government has earmarked a budget of NT$45 billion (US$1.36 billion) for the green energy industry with a strong focus on the development of solar energy sources and power-saving LED lighting, along with wind power generation, biofuels, hydrogen-based energy sources and fuel cells. The industry's production value is expected to increase from NT$160.3 billion (US$5.09 billion) in 2008 to NT$1.16 trillion (US$35.15 billion) in 2015.[3] In addition, according to one of the conclusions reached at the National Energy Conference in Taipei in April 2009, the central government plans to create two low-carbon communities in each of Taiwan's 16 counties and 7 larger cities within 2 years. Six of the larger cities are expected to achieve low-carbon designation within 5 years. To assist in this effort, in June 2009 the Environmental Protection Administration (EPA) established the Office of Eco-community Promotion Program, which is responsible for working out carbon reduction measures in five areas: renewable energy, energy conservation, resource recycling, green architecture and green transportation.

8.2.1.3 Colombia, Peru

Both Colombia and Peru have in recent years placed increasing emphasis on combining strong economic growth with environmental sustainability and social development. In the case of Colombia its 1991 Constitution makes explicit reference to sustainable development (including 26 articles on environmental issues) and has been supported through the implementation of accompanying regulations and institutional structures. Most recently this has included a commitment in 2011 by Colombia's president to create a new Ministry of Environment and sustainable development.

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[2] http://www.thenewage.co.za/11907-9-53-China_adopts_a_green_growth_policy_in_its_next_fiveyear_plan

[3] http://taiwanreview.nat.gov.tw/ct.asp?xItem=69656&CtNode=1337

Peru has historically had less of a focus on environmental issues and the difference in government approaches between Colombia and Peru and the potential impact on industrial environmental practices was the driver behind their selection as case studies. Since the undertaking of the research Peru has considerably increased its focus on environmental issues, including an autonomous ministry of environment and strict requirements for environmental, social and health impact assessments and accompanying management plans.

8.2.2 Global Ecological Ethics of MNCs and Their Sustainable Development in Emerging Economies

In order to support the growing green growth expectations of emerging economies, MNC subsidiaries need to incorporate green development strategies and play a significant role in the advancement of global ecological ethics (Rojsek 2001). In recent research, MNCs are found to perform better in business ethics and more responsible in environmental protection (Jemali 2008), although few managers see a strong connection between their environmental investments and a significant upturn in their financial performance (Brown et al. 1998). Since 1998, there have been significant increases in sustainability reporting among the world's 250 MNCs (Kolk 2003). There are different perspectives concerning incentives for MNCs to engage in CSR activities. For example, from an empirical perspective sustainable business practices are found to influence corporate performance positively in the long-term (Lopez et al. 2007). In Cetindamar and Husoy (2007)'s research, the major benefits of participation in the United Nation's Global Compact initiative was the acquisition of better networking opportunities and economic opportunities, along with reduction of waste and labour costs. Yu and Lin (2008) highlight that organizations compete not just for resources and customers, but also for political power and institutional legitimacy, for social as well as economic leverage in the view of institutional theory. Other academic researches has focused on understanding the nature of corporate social behaviours as a part of overall corporate brand image (Sing et al. 2008).

Jemali (2008), in a research based on stakeholder framework, finds that MNCs and their subsidiaries make systematic efforts to manage a wide spectrum of stakeholder relationships. Abreu et al. (2005) in their exploration of the CSR experience and practice of enterprises in Portugal, identifies five key stakeholders: consumers, suppliers, the community, the government and the environment. Organizations, especially MNCs, from the stakeholder perspective are expected to manage responsibly a wide range of stakeholder interests across increasingly permeable organizational boundaries, and acknowledge a duty of care towards both traditional interest groups as well as other stakeholder groups—such as local communities and environmental non governmental organizations (Simmons 2004).

Besides the stakeholder perspective, the static taxonomic CSR descriptions are highlighted in many studies to explain MNCs' business ethics behaviours (Carroll 1979; Wood 1991). For example, Wood (1991) offers a model in which a researcher can consider the principles that motivate a firm's social responsibility actions at three levels of analysis: institutional, organizational and individual. The motivation for a firm's social responsibility actions may stem from the principle of legitimacy. Firms' responsiveness, according to Wood (1991), constitutes an action dimension that is needed to complement the normative and motivational component of social responsibility and is rooted in knowledge about the external environment and in rigorous environmental scanning/analysis. This knowledge can then be used to devise strategies for adapting to the new societal environment.

In conclusion, environmental protection issues cannot be treated as mere technical issues, particularly given the serious negative social and health impacts that uncontrolled pollution can cause (Hoffman and Ventresca 2002). In general, local institutional authorities, including legislative bodies, governments, and NGOs, require firms to comply with laws, rules, standards, policies, and public pressures regarding environmental protection. Although substantial knowledge concerning MNCs' role in economic development exists (see, for example, Vernon 1971; Dixon et al. 1986; Blomstrom 1989; Lall 1993; Hansen 1995), there is only limited empirical study relating to the environmental contribution of MNCs to emerging economies (Moser 2001; Tsai 2002; Child and Tsai 2005). Indeed, despite the recognition of the vital role that MNCs play in the sustainable development of emerging economies (Hunt and Auster 1990; Cairncross 1992; Greeno and Robinson 1992; Schmidheiny 1992; Smart 1992; Avila and Whitehead 1993; Levy 1995), there is limited detailed research examining the contribution of MNC subsidiaries.

Although earlier studies emphasise a motivation on behalf of MNCs for investing in emerging economies based on the "Pollution Haven" hypothesis (Walter 1982; Duerksen 1983; UNCTMD 1993; Clapp 1994; Hansen and Gleckman 1994; Hansen 1995), more recent studies—for example, Jaffe and Stavins (1995), Jaffe et al. (1995), and Christmann and Taylor (2001)—suggest that industrial flight to pollution havens via FDI is exceptionally rare. Indeed a number of studies note that MNCs generally have higher standards than other companies, including local state owned and private companies, and overseas independent companies (Moser 2001), for reasons of superior resources, greater international experience and exposure and higher visibility in the market place (Royston 1985; Pearson 1987; UNESCAP 1988; Warhurst 1994; Tsai and Child 1997). At the same time, local governments in host countries may use the presence of MNCs to justify the implementation of more stringent rules and regulations. The situations faced by MNC subsidiaries in foreign countries are expected to be more complex because of the different social contexts they operate in and the conflicts between headquarters' standards and local institutional requirements as well as the cost from the liability of foreignness. Finally and related to the question of whether MNC environmental behaviour is context-dependent or independent, lies the important issue of whether there are variations in MNC environmental behaviour between developed countries and emerging economies, as well as between MNCs operating in different emerging economies (Knogden 1979; Ausubel and Victor 1992; Brown et al. 1993). This line of inquiry is marked by a lack of general consensus and invites further investigation.

8.2.3 Theoretical Framework

Pressures on organizations to conform to the requirements of environmental protection originate from three systems: *regulative*, embodying laws, governmental regulations, policies, standards, and rules; *normative*, concerning organizational routines, social responsibilities, and work procedures; and *cognitive*, building upon public awareness of environmental issues (Pfeffer and Salancik 1978; DiMaggio and Powell 1983; Oliver 1991). Under such pressures, organizations are *institutionalised* and *legitimised* by aligning themselves to the requirements and expectations of their institutional contexts (DiMaggio 1988; Meyer and Scott 1983). The complexity of legitimacy for MNC subsidiaries, given the multiple constituencies embedded in different operational contexts, creates further pressure to conform (Kostova and Zaheer 1999).

In examining MNC contexts, Kostova and Roth (2002) propose an 'institutional duality' model. According to Kostova and Roth, two institutionalizing forces confront MNCs. The first comes from local institutions, as discussed above. Moreover, as foreign firms, MNCs face additional local institutional pressures that derive from the 'liability of foreignness' in a host country setting (Zaheer 1995). "Liability of foreignness" is usually referred to as 'all additional costs a firm operating in a market overseas incurs that a local firm would not incur' (Zaheer 1995: 343). For instance, an MNC often face stricter regulatory requirements from local government or tougher normative and cognitive pressures from civil society organizations and the public at large (Child and Tsai 2005).

The second institutionalization force derives from the internal environment to the MNC organization in which subsidiaries or subunits must gain internal legitimacy as they are required to be integrated as a whole organization. There are studies on the approaches of MNC standardization. For enacting ecological sustainability in the MNC, Andersson (2005) proposes that supervisors, as well as middle-and low-level managers, provide the critical link in forwarding the message of environmental sustainability from top management to lower-level employees within an MNC.

According to Kostova and Zaheer (1999), legitimacy is defined as 'the acceptance and approval of an organizational unit by the other units within the firm and, primarily, by the parent company' (Kostova and Zaheer 1999: 72). MNC headquarters desire internal standardization (i.e. internal legitimacy) to optimise global performance and minimise potential reputation risks. In particular MNCs' poor environmental performance in one country can easily impact the reputation of the MNC as a whole. All these forces require MNCs to standardise activities of subsidiaries across host countries. In many cases, these two institutionalization forces, or institutional duality, can conflict with each other (Kostova and Roth 2002;

Westney 1993) and stretch MNC subsidiaries in their strategic choices of adapting to and accommodating local institutionalization pressures, versus internal standard practices (cf. Bartlett and Ghoshal 1989; Hansen 1995; Levy 1995).

While classical institutional theory viewed institutionalization as a constraint, scholars have recently proposed that firms can develop institution-based competitive advantages (cf. Peng 2002). Since MNCs may have advantages that are built upon their extensive experiences across countries, Kostova and Zaheer (1999) argue that MNCs can find it easier to understand and adjust to institutional pressures of a country that is institutionally similar to the ones in which the MNC has already established operations. In addition, the size of MNCs and the considerable resources at their disposal are important sources of potential competitive advantage, both in their ability to bargain for better investment terms and their capability to improve or undermine environmental protection standards in emerging economies (Choucri 1993). Thus, whether MNCs strategically choose to implement their internal standards and global practices, or to adopt a more ‘hands-off’ approach is complex, depends not only on the existence of the institutional duality, including the liability of foreignness, but also on the overall strategies of MNCs. In other words, MNC perceptions of environmental protection issues as a potential threat (Walley and Whitehead 1994) or opportunity (Porter 1991; Porter and Linde 1995; Wheeler 1992) can have significant influence on their responses to local institutionalization pressures (Dutton and Jackson 1987).

8.3 Research Methods

The research was undertaken as two separate investigations, incorporating different research methodologies to examine common themes.[4] In both cases the research methodologies enabled examination of the response by MNC subsidiaries to environmental protection issues, as well as investigation of the relative importance of external and internal factors for their environmental responsiveness.

The petroleum industry was selected because the firms being researched belong to the group of general manufacturing companies leading the way in environmental protection driven by a range of factors including (1) many of the firms in older industries may face environmental problems that are relatively comprehensive and complex, at least compared to many newer industries. (2) They may have longer histories (often adversarial) of dealing with regulatory agencies, leading to an emphasis on active behaviour to alleviate and forestall any negative developments in their regulatory environments (Brown and Karagozoglu 1998).

[4] Although the use of separate research methodologies is recognised as a potential weakness of the research, the similarity in research focus and findings from the two different geographic contexts and industrial sectors, as well as the overall exploratory and innovative nature of the research were considered adequate to counter this.

8.3.1 Colombia and Peru

Three factors supported selection of the Colombia and Peruvian petroleum industries for the Latin American component of the research. First, in both countries there is considerable expansion by multinational oil corporations, attracted both by the presence of considerable potential hydrocarbon reserves and macroeconomic frameworks promoting FDI (Forsyth 1997; Oil and Gas Journal, Apr. 19 1993:30–31). Second, in both countries the majority of hydrocarbon activity occurs onshore in remote and environmentally sensitive areas. Finally, despite these similarities, Colombia and Peru have historically adopted differing approaches to environmental management. In particular Colombia through an autonomous ministry of environment has emphasised a regulatory approach based on command and control instruments, whilst Peru initially through an environmental unit within the Ministry of Energy Mines and more recently through the Ministry of Environment has managed environmental issues primarily through *auto-regulatory* instruments that emphasise trust and reciprocity (Fukuyama 1995) between industry and government.

In Colombia and Peru, a mixed methodological approach was used for the research (Kiggundu et al. 1983), which incorporated cross-country and cross-company analysis. A structured questionnaire incorporating a number of organizational, attitudinal and company policy and procedural based variables was used to examine the environmental responsiveness of companies. The questionnaire and case studies were used to investigate the motivations behind corporate environmental responsiveness (Yin 1994).

The questionnaire was developed using a number of sources (Hampden-Turner 1995; Moser and Kalton 1971; Nitsche 1996; Oppenheim 1966; Payne 1951; UNCTMD 1993) as well as preliminary information gathered from over 20 initial meetings with different company, governmental and non-governmental organizations in Colombia and Peru. Approximately eight iterations of the questionnaire were undertaken, including piloting with three companies (two in Colombia, one in Peru), before arrival at the final version. A methodology proposed by the Gallup Organisation (Dunlap et al. 1993: 8), was used to translate the questionnaire.

Over a 6 month period, the survey was personally administered with responses obtained from 16 companies in Colombia and 12 in Peru, accounting for 84% and 63% of all oil and gas companies in the two countries. After initial analysis of the survey data a total of approximately 20 further semi-structured interviews were undertaken with the Bogota, and Lima based heads of environment affairs. Building upon the initial questionnaire findings, the purpose of these interviews was to further explore the perceived importance of different internal and external factors for corporate response to environmental issues. Over the same period, a further series of interviews (approximately 25) were held with individuals from the respective Ministries of Environment, local petroleum associations, academic institutions and NGOs.

Case study research was then undertaken with five companies involving extensive field based study combining interviews with participant, and observant research.

The overall objective was to better understand how internal operational policies and regulatory requirements were being operationalized in the field. In Colombia, research over a 3-month period focused on three companies (one MNC, two overseas independent) operating in the Eastern oil-producing region of Casanare. Approximately 40 interviews were held with operational staff, along with local government authorities, NGOs and community representatives. In addition there were a number of opportunities to undertake participant and observant research including for example 10 days spent living in an oil production facility. Through “shadowing” (Mintzberg 1989) the production manager and environment/community affairs officers, it was possible to obtain a true insight into their day-to-day activities.

Subsequent to Colombia a month was spent in Peru undertaking case study research with two MNCs, but focusing largely on the activities of one MNC with operations in a remote jungle region of Peru. In total 15 interviews were conducted. Throughout the research process all company interviews (Colombia and Peru) were tape-recorded under a guarantee of confidentiality. Cases were compiled based upon transcripts of the data, as well as extensive notes taken throughout the research period.

8.3.2 Mainland China and Taiwan

Although the Greater China region incorporates Mainland China, Hong Kong, Macao and Taiwan, Mainland China and Taiwan were chosen to represent the conditions in the region for two reasons. First in Mainland China and Taiwan, there is a higher concentration of MNC-led pollution intensive manufacturing activities relative to Hong Kong and Macao, where service industries dominate. Second, Mainland China and Taiwan have adopted contrasting approaches to environmental management. In particular Taiwan, with its status as a newly industrialised country (NIC), has adopted the more rigorous approach. There is an autonomous Environmental Protection Administration (EPA) to implement an automated environmental monitoring system at key industrial parks, and to promote the international environmental standard ISO14000 widely. This differs from Mainland China, where activities of the Chinese EPA have been eclipsed by a focus on poverty alleviation measures. Chinese environmental laws and regulations also suffer from an ambiguous chain-of-command, where environmental jurisdiction can sometimes be difficult to delineate between various powerful ministries and between local and central governments.

The sensitivity of the research issue, as well as the Chinese managerial emphasis on ‘face-to-face’ interaction underpinned the application of a case study research methodology. A total of 10 cases were compiled, including three MNCs with operations in both Mainland China and Taiwan, two Taiwanese firms and two Chinese state owned enterprises (SOEs). For each case study, semi-structured interviews were conducted with regional managers and Health Safety and Environment (HSE) regional directors. The interviews first considered the strategic decision making of a fixed issue known to create environmental impacts. They then explored related themes such as corporate environmental policies and guidelines, senior management perception towards environmental protection issues, the level of strategic importance, perception of competitors' environmental performance and the resources (financial and human devoted specifically to environmental protection). The same approach was repeated at the plant level with operations manager and plant HSE managers and coordinators. A total of 53 corporate-related face-to-face interviewees were undertaken covering cities such as Taipei, Taichung, Kaohsiung, Taoyuan (in Taiwan), Shijiazhuang, Beijing, Shanghai, Suzhou, Ningbo, Guangzhou and Hong Kong (in PRC).

Triangulation of research findings was achieved through an onsite audit using the standard industrial hygiene/safety and environmental site reconnaissance protocols (the researcher in this case was a trained professional environmental engineer prior to becoming a management academic and practitioner) following the interviews, including random interviews with workers as well as through interviews with regulatory agencies and key stakeholders (environmental NGOs, workers' unions, local university professors, opinion leaders, suppliers, customers, and contractors in charge of waste disposal).

In total the study incorporated 1 year of fieldwork divided equally between Mainland China and Taiwan. All the interviews were tape recorded in the first instance in the native language of the interviewees. Full transcripts were then developed in the corresponding languages and translated into English by a language professional. The authors consequently checked the transcripts against the original recording for reliability and accuracy. Confidentiality was assured throughout the process via withholding of names of the interviewees and organization identities.

8.4 Research Findings

8.4.1 MNC Response to the Liability of Foreignness Caused by Regulatory Pressures

A consistent finding from both research areas was the importance of (local) regulatory systems for the environmental responsiveness of MNCs and indeed all other types of companies. In this regard Fig. 8.1 highlights the factors identified as being important for MNC environmental performance in Colombia and Peru as whole, while Fig. 8.2 highlights the importance of different factors important for all companies operating in Colombia, and Peru respectively. In all cases the predominance of local legislation is evident. Thus the more strict environmental policies and accompanying enforcement mechanisms, the more likely MNCs and other company types are to improve their environmental performance.

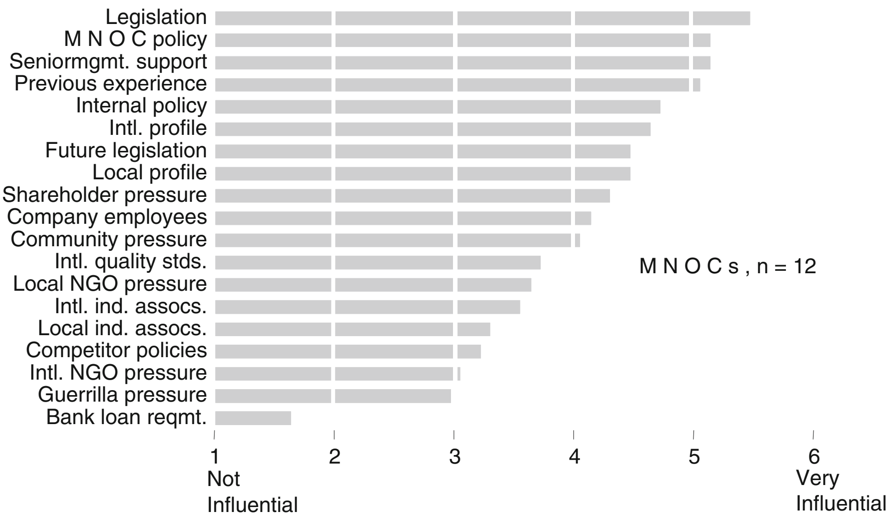

Fig. 8.1 Explanation for MNC response to environmental impacts: Colombia and Peru combined (Source: Based on Moser (1998, 2001) with new information added)

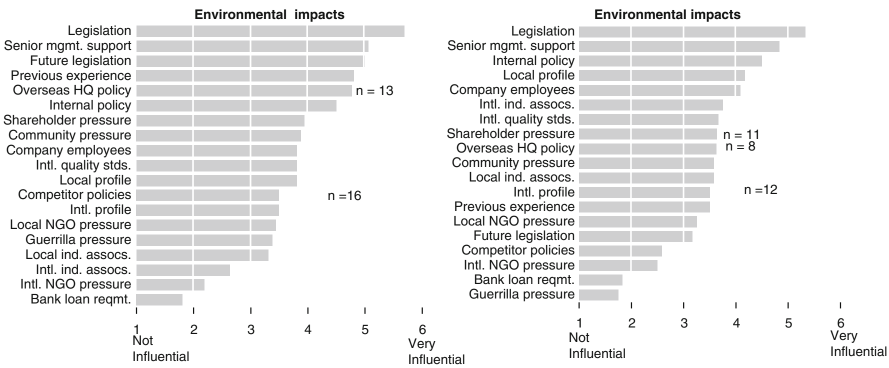

Fig. 8.2 Explanation for all company response to environmental impacts: Colombia and Peru separate (Source: Based on Moser (1998, 2001) with new information added)

As shown in Fig. 8.1, after legislation, MNC internal policies and procedures were regarded as the most important factor. The presence of strong local legislation provided an external incentive to implement internal policies to their fullest. As an MNC manager in Colombia acknowledged:

> Certainly without an environmental police authority, the public relations impact would have been less and the operational impact would have been far less. We might actually have done some things in ignorance. We might have done some things we wouldn't have wanted to do . . . And that is why you need an environment authority, if for no other reason than to be a check and balance.

Similarly local legislation was critical in influencing the environmental behaviour of MNCs in Mainland China and Taiwan. As an operations manager in Mainland China commented:

> Do you know that Mainland China has some of the toughest standards in the world? Unlike Taiwan, Chinese local regulators . . . only enforce the regulations for the sake of obeying the rules from the higher authority. It's frustrating for us considering that Mainland China does not have the requisite infrastructure to support their regulations. We often have to invest in all kinds of infrastructure and apply our most up-to-date technologies to be in compliance with the local regulations. It's costly and ridiculous. . . We are required by our internal policy to adopt either the internal or the local standards, whichever are more stringent.

At the same time not only did the research highlight the importance of legislation, but also evidence of the Liability of Foreignness being used by local legislators wishing to make an example of MNCs, so as to provide an indication to the rest of the industry of the importance of environmental protection. Relative to other types of companies, MNCs are easily identifiable and likely to respect penalties for non-compliance. Accordingly, the regulatory authorities impose *stricter* requirements upon MNCs, with the intention of inducing the rest of the industry to incorporate responsible environmental business practices. For instance, in Mainland China, governments often expect MNCs to introduce their global best practices and technologies and therefore become benchmarks for local firms. Similarly in Colombia, the government identified the petroleum industry as the most important one for compliance with new legislation (introduced in 1994), even though there were other more polluting sectors. The underlying rationale was the predominance of MNCs within this sector and the relative ease with which they could be made to comply. These cases exemplified strategic manoeuvring of the host governments to derive the maximum benefits from institutional conformity.

Notwithstanding the greater expectations on MNCs, both pieces of research showed that MNCs (through their subsidiaries operation) were more responsive to environmental protection issues in emerging economies than other company types. Table 8.1 illustrates the responses from different types of petroleum companies operating in Colombia and Peru to a number of organizational, attitudinal and policy-related dimensions of corporate environmental behaviour. These empirical results demonstrate that for each of the variables considered, MNCs displayed the most proactive response to environmental issues.

MNCs showed greater responsiveness in terms of perceived importance of environmental issues, deployment of organizational and financial resources, senior management participation in environmental issues and the overall integration of environmental protection issues in their management practices. Interview data further highlighted the benefits MNCs enjoyed of global networks, through which critical resources, such as other experiences, specialised staff, and financial resources, were drawn upon to support overseas expansion. By contrast, these resources and experiences were generally not available to other types of companies.

Table 8.1 Corporate environmental behaviour by company types and country

	All companies (n = 28) %	MNCs (n = 12) %	Overseas Independent (n = 10) %	Local (n = 6) %	Colombia (n = 16) %	Peru (n = 12) %
Attitudinal variables						
Companies identifying environmental issues of critical or high importance	79	100	50	83	88	68
Belief that good environmental management offers business opportunity	46	50	40	50	38	59
Organizational variables						
Presence of an environment department	64	83	50	50	81	42
Presence of in-house environmental specialists	39	58	30	17	50	25
Head of environment department reporting to company president	33	40	20	33	39	20
Senior management involvement in environmental issues	71	84	70	50	81	58
Estimated funding for environmental issues (% of CAPEX)	10	12.1	6.9	13.5	13.4	6.2
Presence of annual funding for environmental issues	71	75	50	100	81	58
Internal training on environmental issues	64	75	70	33	68	58
Policy and procedural variables						
Internal corporate environmental policy	82	100	60	83	88	75
Published external environmental policy	29	50	0	33	31	25
External reporting on environment	54	67	40	50	56	50
Inclusion of environmental costs in initial project feasibility assessments	68	83	50	66	69	66
Use of environmental criteria in contractor selection	32	58	10	17	35	33
Monitoring of contractor environmental performance	14	17	10	17	19	8
Presence of complementary environmental social investment projects	61	75	50	50	81	33

Source: Based on Moser (1998, 2001) with new data added

The following quote from Mainland China supports the idea of greater responsiveness among MNCs to environmental protection issues:

> In general, MNCs are more progressive than our SOEs . . . As far as the records are concerned, MNCs have demonstrated good environmental stewardship in Mainland China. There are many things we can learn from the big MNCs. (Senior Officer, China National Environmental Protection Agency)

Taiwan is probably the outlier among the four countries considered because the difference in environmental response levels between MNCs and large, reputable local companies was small. MNCs were nevertheless motivated to introduce best practices as competitive advantage over local firms. This could be seen from the following quote:

> [we] feel that our big local corporations are as good as the foreign MNCs in environmental protection . . . We have certainly come a long way. (Senior Officer, Taiwan Environmental Protection Administration)

One explanation for the convergence of environmental protection attitudes and practices between MNCs and large local corporations in Taiwan is that the local government has had a well-established monitoring and control system in place since the early 1950s when Taiwan opened its market to foreign firms. Therefore, local firms, particularly large ones, have been driven for long time to match the standards of environmental protection as MNCs.

8.4.2 MNCs Responses to the Liability of Foreignness Caused by Normative Pressures

According to institutional theory, institutionalization forces of a normative system come into existence through the development of rules-of-thumb, standard operating procedures, occupational standards, routines, conventions, training programmes, and education curricula (Hoffman 1999). In this respect, the rapid internationalization of many MNCs and the accompanying increased environmental expectations provide further explanation for their own internal growing global environmental responsiveness. As an example and based upon their own well-established global policies and procedures, MNCs frequently required local contractors to meet their standards in terms of quality, delivery, and environmental criteria.

> We have a very comprehensive set of health, safety and environmental (HSE) requirements . . . so it is possible that somebody who has a higher bid than somebody else will be awarded the work because of factors like HSE. In fact we specifically disqualify some companies if they don't meet the minimum standard. (Environment Manager, MNC, Colombia/Peru)

In this case, MNCs have distinctive advantages over local companies, as one environmental manager in a local state owned enterprise (SOE) said:

> We don't use environmental criteria in the selection of contractors. Contractors simply have to comply with the environmental impact assessment and environmental management plan studies. We would not choose a firm simply because it had an environmental focus. (Environmental Manager, SOE, Colombia/Peru)

This was especially the case for MNCs with new or recently established operations, where the flexibility in choice and strategic benefit from selecting the most up-to-date environmental technologies and practices is greatest. For instance, MNCs in Mainland China with manufacturing operations configured to global standards are able to save on process design time and adhere to a set of resource-saving maintenance codes. This enhances central planning capability as operations become streamlined on a worldwide level. In the oil industry there are examples of companies applying technologies developed in the western world to a developing country context. One MNC in Colombia, for example, widely applied the practice of drilling multiple wells off a single site using horizontal drilling methods. This approach, originally developed in the USA, enabled this MNC to be more efficient in its drilling operations, as well as reduce its environmental impact.

In both study areas, external entities (i.e. regulatory authorities, contractors and NGOs) in regular contact with the different types of companies also indicated that MNCs displayed the most proactive response to environmental issues. In particular, contractors—who feature prominently in both industries—emphasised the more stringent environmental standards imposed by MNCs, as illustrated by the following quotes:

> [MNC company name] wouldn't let me begin my work until I submitted an environmental management plan. That would never happen with a Colombian company. (A Colombian contractor)
> We learned a great deal from the foreign MNCs in the area of safety, health, and environment. They are a lot more advanced when compared to our local clients. (Taiwanese contractor)

8.4.3 MNC Responses to the Liability of Foreignness Caused by Cognitive Pressures

A *cognitive* system embodies taken-for-granted rules and symbols (Hoffman 1999). Organizations act according to cultural consensus or compliance with cognitive rules. In a host country, such cognitive pressures arise largely from the actions of local actors (including civil society and media organizations) who in the capacity of 'informal legislators' leverage the concern MNC have over their global reputation to drive improved environmental performance.

MNCs tend to be more concerned about their global reputation and prestige than local companies or overseas independent companies. Incidents linking MNCs with negative environmental experiences such as Union Carbide and the Bhopal chemical leak (Gladwin 1977; Shrivastava 1992) and the Exxon Valdez Alaska oil spill clearly demonstrate the negative impact—financial and otherwise—that poor environmental management can have for MNCs. Globalization of international pressure groups and the revolution in global telecommunications further make it extremely difficult for MNCs to restrict responsible environmental practice to a developed country context. As one senior Taiwanese manager stated:

> Look at what happened to Union Carbide. It took them years to be in the black again. In this day and age, when information diffuses at a more than rapid speed, we can't and let me

> repeat, we can't afford to make this kind of fatal mistake. We need to be in a leading position in our dealing with HSE matters.

Similarly in Colombia, an MNC environment manager acknowledged the importance of reputation:

> What we come back to is what [company name] is afraid of . . . because . . . they do more than is required by the local regulations . . . if the local regulations calls for nothing, they will do more because they do not wish to be criticised in any . . . country . . . the image they have as a green company . . . they believe . . . will be destroyed by one case. One hundred countries OK, but the final one you are criticised in and that's it. People believe that one exception, so they don't take the chance.

An MNC manager in Mainland China shared this concern about the relationship between good environmental behaviour and an MNC's ability to undertake its operations:

> Our reputation in HSE is our license to operate internationally. If we mess up in one country, with today's advanced telecommunication technology, the whole world knows about it. With a corporation of our size, we can't afford any mishaps in our HSE conducts. Once our corporate image gets soiled, it takes a long time to recover and this signifies tremendous financial loss, not to mention our relationship with our clients and customer.

In Peru, local and international NGOs closely monitored the activities of MNCs; meanwhile, local and overseas independent companies undertook their activities almost unnoticed. In Taiwan, NGOs played an important monitoring role, especially of the large MNCs. Again, cognitive institutionalization pressure is evident. An MNC manager in Taiwan stated:

> I must credit the NGOs here for promoting greater environmental awareness. They keep us on our toes. They move faster than Government. When there is a suspicion that we are exceeding discharging standards, or when they smell something in the air, you will be sure to see them showing up in our plants. They operate a very tight monitoring system.

8.4.4 Internal Standardization vs. Localization Within MNC Organizations

The research findings also showed examples of how MNCs used their good environmental experiences, policies and practices as part of their strategy to competitively position themselves in the host country. For instance, many MNCs regarded the Greater China region, including mainland China and Taiwan, as a key strategic geographic area. To enter the local markets, MNCs positioned themselves as responsible global citizens and sought to persuade local governments, NGOs, and local media that their investments in these areas would not only bring advanced technologies in production facilities, but modern day environmental practices. Similarly in Colombia and Peru, MNCs perceived good environmental behaviour as important, both in terms of future potential access to exploration blocks and expedience in obtaining environmental licenses and permits for any existing operations. As one MNC manager in Colombia stated:

> The decision that the environment was important was not entirely moral. It was a business decision, that one has to behave to a pretty high standard in order to gain access and to continue to maintain access in the world today.

The best environmental behaviour was observed where MNCs had recently established facilities and where there was strong local legislation enforcement. Although MNCs' subsidiaries from the same MNC operating in different emerging economies are governed by similar internal guidelines, they retain the option to respond differently according to their strategic intent. In Mainland China, owing to the political rivalries between the central and the local governments, MNC subsidiaries often chose to enforce certain components of the corporate HSE programs to match the local development objectives. A similar sentiment was expressed by an MNC manager in Taiwan who perceived that tougher regulations could be turned into an opportunity rather than a threat:

> I don't consider being green as a threat. Tougher HSE regulations push us to think creatively. I wouldn't have come up with some of our most notable cost-saving measures in this plant if it were not for the change in regulations. The local context also helps us to think out of our box, because they often represent unfamiliar challenges. Now the Taiwan EPA invites us to give classes to their law-enforcement officers and other companies. I suspect we will be running an environmental consulting arm in the not so distant future.

There existed variations in environmental behaviour between MNC subsidiaries operating within the same country and in different countries. As shown in Table 8.1, the priority given to environmental issues for all companies, including MNCs, was significantly higher in Colombia than in Peru. This can be largely attributed to Colombia's more stringent regulatory framework.

In this regard in many MNCs, the headquarters issued policies and guidelines that govern the minimum expected performance standards. This control mechanism delegated some autonomy to subsidiaries and enhances flexibility in decision-making and execution. If the corporate minimum standards meet the requirements of local legislators, a subsidiary may not adopt the best global practices in a given host country. In Colombia, some MNC subsidiaries saw a strategic advantage in applying the latest environmental practices, while others saw no benefit. The variation in perceived strategic advantage was often dependent on such factors as previous experience and future plans within the host country. As an MNC headquarters' environment manager acknowledged:

> All our overseas subsidiaries are provided with guidelines (which they must apply) . . . as they see appropriate, but local legislation is most important . . . We have so many businesses and . . . activities, that it would be impossible to govern them all (Moser 2001: 300).

The practical implications were evident in the environmental strategy of this MNC's Colombian subsidiary. In the decision whether to use single, or double-lined gasoline storage tanks at the company's petrol stations, despite an internal policy of double-skinned tanks, the subsidiary elected for economic reasons to use single-skinned tanks. Although not in accordance with internal policies, nor the best environmental option, their use was compliant with relevant Colombian legislation.

Thus, an MNC's commitment to good environmental performance becomes a 'bargaining chip' that is contingent on the balance of the attractiveness of a given local market versus the extent of the liability of foreignness imposed by local institutional requirements. In countries where local institutional pressures impose high environmental performance expectations and the market is strategic, better environmental performance is likely to be evident in the MNC subsidiary. For instance, in the wealthy coastal Chinese provinces where environmental issues are highly publicised and of concern to many, MNCs were required by local governments to apply the most up-to-date environmental technologies. Moreover, MNCs that had a historically excellent environmental protection record were granted more favourable conditions in their subsequent investment projects. In contrast to the poorer inland provinces, local governments were known to sacrifice environmental well being for greater foreign investment and MNCs would often respond adaptively by introducing the minimum environmental standards instead of the best practices. The same pattern was observed in Colombia and Peru, with the former placing greater emphasis on good environmental practice from MNCs and the latter more concerned with the short-term economic benefits of hydrocarbon activity.

8.5 Discussion

This section considers the research findings in relation to the theoretical framework. Based upon institutional theory, the paper proposed that the environmental responsiveness of MNCs can be understood in terms of institutional duality through the combination of external and internal institutional pressures.

The study findings clearly illustrate that fundamental institutional pressures from a host country's external environment were imposed by regulatory and cognitive pillars. Moreover, MNC foreignness (and the associated 'liability of foreignness') is deliberately exploited by local regulators to stimulate improvements in environmental performance across the industry as a whole. Similarly whilst of lesser significance, the research findings shows both the importance of cognitive institutional pressures for MNC environmental performance, as well as how MNCs' concern for their global reputation is exploited by local stakeholders to also drive improved environmental performance and/or other objectives (e.g. campaigning against FDI). Indeed leveraging of MNCs liability of foreignness by other (non government) stakeholders was most apparent where there was a relative absence of 'formal' regulative pressures (e.g. Peru, inland China), and as such 'informal' cognitive pressures were seen as the most effective means of influencing MNC behaviour.

The research findings also show that the institutional duality is created when MNCs attempt to maintain effective control over subsidiaries through internal institutionalization processes. Such internal institutional pressures are more likely developed based upon internal normative pressures for MNC subsidiary environmental performance. As part of the tendency within MNCs to internally standardise polices, procedures and practices world-wide, MNC subsidiaries adopt intra-organizational institutionalization with their corporate headquarters and other subsidiary operations.

In this respect MNC headquarters—through standardised environmental policies and procedures, internal auditing, cross postings of personnel, lesson and technology sharing and other mechanisms—exert endogenous, coercive standardization or a 'ritual conformity' pull on their subsidiaries (Meyer and Rowan 1977). Such a strategy requires legitimacy both within (i.e. with other companies) and external to their respective industries (i.e. with governments, NGOs, etc.) and motivates MNCs to adopt environmental standards consistent with best practice as perceived by the local—and increasingly by the international—communities, cf. raising rivals' cost (Nehrt 1998).

The fact that relative to other company types MNCs face a broader range of institutional duality stemming from external and internal of institutional pressures, combined with their liability of foreignness assists explain the greater overall environmental responsiveness of MNCs relative to other company types. The institutional duality or the variance of external versus internal institutional pressures for MNCs calls attention to the concept of 'strategic choice' (cf. Child 1972). Indeed, as Kostova and Zhaheer (1999) note, rather than being a threat or becoming isomorphism to local organizations under external regulatory requirements, MNCs can potentially benefit from multiplicity of institutional environments and pressures within and across direct countries. In this regard the institutional duality gives rise to distinctive advantages of MNCs as the research findings demonstrate that in addition to a perhaps more passive/reactive response to institutional pressures, there can also be a more proactive undercurrent, in particular, as part of MNCs' search for local legitimacy and competitive advantage. When in their interest, MNCs are more likely to exploit their own internal standards, policies and experiences to gain competitive advantage. Similarly MNCs seek to overcome the liability of foreignness in cognitive systems by creating good corporate reputations by displaying better environmental performance than local firms. In these instances the liability of foreignness stemming from local institutionalization requirements is viewed as a strategic opportunity and not necessarily a threat.

However, as also identified, not all MNC subsidiaries sought to align themselves with internal MNC headquarter expectations. In particular when MNC corporate headquarters exercise control over their subsidiaries via a 'loose-coupling' system (Meyer and Rowan 1977), subsidiaries may be more responsive to the local legislation, culture, norms and stakeholders expectations. The issue of institutional duality and legitimacy thus creates an interesting dynamic within MNCs. In this regard the underlying need for local legitimacy within the host country provides an explanation of the importance of local legislation. Unless MNC subsidiaries align themselves with the local institutions, they risk losing their *license to operate*. When the liability of foreignness becomes high due to policy inducement, subsidiaries of MNCs may opt for short-term profit-maximization and fail to align themselves with the internal standards, depending upon what MNC headquarters will tolerate vis-à-vis local tailoring. To the contrary, the desire to standardise is particularly profound when MNCs pride themselves as the leaders in environmental management and technology and when host-to-home country feedback fails to generate adequate financial performance.

8.6 Conclusions

This study is exploratory but shows that MNCs in the petroleum and chemical sectors, through the activities of their subsidiary operations in selected countries in Latin America and the Greater China Region, have an important role to play in the environmental protection of emerging economies. In particular, the study highlights that given the right external institutional and internal organizational context and incentives that MNC subsidiaries growing need for green development from these countries brings higher expectation for MNC subsidiaries and both local and multinational firms need to consider the changing institutional environment.

The research shows that, relative to local companies, MNCs are more environmentally responsive. The greater resources and international experiences of MNCs, as well as their greater sensitivity to local legislative demands, negative media publicity and NGO pressures, provide the primary explanation for this. The implication is that FDI, in general, is beneficial to environmental protection in emerging economies. Through active engagement with local institutions MNCs play a key role in diffusing more advanced home country-originated technologies and management know-how. The research, however, suggests that MNCs are not consistent in their application of environmental policies and practices world-wide. The environmental performance of MNC subsidiaries is in practice closely linked to the local context of operation and any accompanying pressures—both formal and informal—for environmentally responsible business practice. This moves the debate on globalization versus localization beyond the issue of control to a more cognitive level.

The conceptual framework illustrates the applicability of institutional theory to a better understanding of the role of MNCs in the environmental protection of emerging economies. The article shows that MNCs' responsiveness can be understood in terms of a combination of (external) regulative and cognitive and (internal) normative institutional pressures. The dominance of the former in the environmental performance of MNC subsidiaries illustrates how important it is for emerging economy governments to actively to manage the environmental impacts caused by MNCs and other company types operating within their jurisdiction.

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Chapter 9
Environmental Innovations and Financial Performance of Japanese Automotive and Electronics Companies

Michael Angelo A. Cortez and Cynthia P. Cudia

Abstract Sustainability reporting as facilitated by the Ministry of Environment's environmental accounting and reporting guidelines has been standardized in Japan for over a decade now. Product and process improvements pertinent to environmental innovations are measured in environmental costs. Following literature on the resource-based view perspective, this chapter describes the positive impact of environmental innovations on financial performance. Alternatively, the slack availability of resources perspective describes the reverse effect of the relationship, i.e. financial performance positively affects investments in environmental innovations. Finally, we investigate the existence of virtuous cycles between the constructs and how tangible and intangible benefits accumulate within the context of greening businesses.

Keywords Sustainability • Environmental accounting • Automotive • Electronics • Financial performance

9.1 Introduction

Several issues of environmental neglect and depletion of natural resources have come with the advent of globalization and the emergence of multinational enterprises (MNEs), particularly those of sustainability, social responsibility and

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governance practices. Thus, it is essential to identify the measures that MNEs perform to preserve the environment.

Sustainability considers the environment, society and the economy, although Japanese value-adding reports significantly accommodate environmental concerns a lot more. Arguably, the environment provides for society, and society establishes the economy. Therefore, environmental concerns encompass societal and economic factors (Senge 2008).

Japan is regarded as one of the countries with high incidences of sustainability reporting. Particularly in the automotive, electronics, pharmaceutical & chemical manufacturing industries, regulation takes a central role in standardizing compliance and adoption of manufacturing companies (Kolk 2003). Environmental innovations started in Japan in response to pollution problems brought by rapid industrialization and economic growth in the 1970s. Product design and process improvements have since been institutionalized to improve environmental compliance.

For the purposes of this study, environmental innovations stem from the root construct of corporate social responsibility (CSR) that evolved into corporate social performance (CSP) or corporate citizenship. CSP has been operationalized in literature as including charitable contributions and philanthropy, environmental management, performance, sustainability and until recently, environmental innovations. Nakao et al. (2005) first proposed environmental accounting as a tool for promoting environmental innovations. Hence, environmental accounting as a framework provided the Japanese Ministry of Environment (MOE) guidelines to capture environmental innovations measured in environmental conservation costs (investments plus maintenance expenses) through product and process improvements.

Japanese automotive and electronics companies are particularly interesting to study because of their overall influence on the global production of goods that involve CO_2 emissions in the manufacturing process and ultimate product use. With the availability of a decade's worth of comparable sustainability reports, the relationship between their environmental innovations and financial performance could be established to determine if greening business strategies are worthwhile.

The growing and varied concerns of stakeholders of a Japanese MNE highlight non-financial reports and disclosures that determine the quality or manner of financial performance. For almost a decade now, sustainability or environmental reports have accompanied financial reports to emphasize social responsibility and governance practices. It is in this light that we investigate the question: how do environmental innovations affect financial performance of Japanese automotive and electronic companies? Or is it the other way around?

This chapter aims to: (1) describe the impact of environmental innovations on financial performance, i.e. the first direction of constructs relationships; (2) explore the reverse relationship where financial performance affects decisions to invest in environmental innovations; and to (3) investigate if virtuous cycles exist between the constructs environmental innovations and financial performance.

The Japanese automotive companies in this study include the global headquarters of Daihatsu, Fuji Heavy (Subaru), Honda, Hino, Isuzu, Mazda, Suzuki and Toyota. For electronics companies, Canon, Casio, Fujitsu, Hitachi, JVC Kenwood, Oki Electric, Panasonic, Sanyo, Sharp and Toshiba were considered. The companies were purposely chosen out of convenience and due to availability of comparable information. The scope of annual financial reports and environmental innovations costs from sustainability reports range from 2001 to 2010, which makes for consistency and comparability.

Investigating the impact of environmental innovations on financial performance highlights the benefits to be gained by manufacturing companies, in general, and subsidiaries and related parties within the extended enterprise systems and value chains of these Japanese MNEs in developing countries. Governments and regulators may likewise promote the benefits of sustainability reporting on social and environmental compliance issues of manufacturing companies. Finally, the diverse demands of stakeholders and customers on profitability and manner of business operations are satisfied through non-financial reporting of greening businesses.

9.2 Literature Review

In 1997, the MOE in coordination with various stakeholders and manufacturing companies developed the guidelines for environmental reporting with the objective of standardizing reporting practices in Japan. This is in response to the absence of international environmental reporting guidelines, cognizant of the provisions of the Kyoto Protocol, and a move to advance the Global Reporting Initiative (GRI) of 1997. Four years after the initial implementation, the Japanese guidelines were revised and since then, environmental reporting has been a standard value-adding non-financial report accompanying the annual financial report of Japanese publicly-listed companies (Cortez and Cudia 2010).

Consequently, DiMaggio and Powell's (1983) institutional theory frames the adoption and standardization of environmental reporting in Japan. Initially through *coercive isomorphisms*, the MOE prescribed the Japanese guidelines at the time the GRI guidelines were being developed. As standardization took place, *mimetic isomorphisms* brought the trickle-down effect to the networks of organizations within the Japanese keiretsu system. Considering that a manufacturer has hundreds of subsidiaries and related parties within Japan and worldwide, the consolidation at the headquarters will only be permissible if the sources of information are comparable, hence, facilitating mimetic activities across the network. Finally, *normative isomorphisms* follow that environmental reporting has been standardized as a practice and that companies publish their reports not just as a simple matter of compliance but as a mode of governance (Cortez 2011b).

The KPMG International Survey of Corporate Social Responsibility 2005 revealed that 80% of the 250 companies examined are reporting in the electronics and computers, utilities and automotive and gas sectors (Hopkins 2007). In their manufacturing activities, greening businesses aim to reduce their carbon emissions and eliminate toxic substances through eco-friendly product designs and energy-efficient process improvements. On the consumer level, products of these greening businesses are subject to energy consumption efficiency, thereby doubling the carbon emissions concerns.

Due to the voluntary compliance of publicly-listed Japanese companies to the Environmental Reporting Guidelines (2002) by the Ministry of Environment, the guidelines have been widely used, and so disclosure of their environmental information has increased from 35% to a majority since 1998. It could be noted that approximately half of the top performing listed companies in Japan are in the manufacturing sector.

Earlier in the decade, Deloitte Touche Tohmatsu, published *The Sustainable Auto Report* in 2001, highlighting the strengths and weaknesses of sustainability reporting practices. While there is genuine environmental concern in the corporate philosophy of automotive manufacturers with detailed discussions on product life cycles, innovation, technological options and eco-efficiency, there are limited discussions on risks and opportunities, as well as short and long-term financial performance. More than half of the reports evaluated in the study scored low on the description of financial implications of environmental or social issues.

Kokubu and Nashioka (2001) surveyed the environmental accounting practices of Japanese listed companies from 1998 to 2000 and found that environmental accounting is restrictively viewed as simply the calculation of environmental conservation costs, although it may be expanded to include corporate management. They criticize the current practice and see the comparability of these costs amongst companies as not particularly reliable yet, because companies conforming to the guidelines exercise much discretion in recognizing and reporting environmental costs. Jasch (2002) details the problems in defining environmental costs as stemming from the lack of standard definition, distorted calculations, access to information, hidden costs and cost internalization.

Ideally, the standardization of sustainability reporting is likely to increase the quantity and quality of reports through the initiatives of the GRI and government regulation (Kolk 2003). This is the very reason that the Japanese guidelines are geared towards the correct understanding, evaluation, and support of the treatment of environmental conservation by enterprises.

Comparing environmental costs and financial figures is helpful in determining trends in the environmental innovations of greening businesses. Kokubu and Nashioka (2002) related environmental costs with the business rationale for sustainability. Consistent with Orlitzky's (2005) theorization of the benefits of corporate citizenship and social performance, Kokubu and Nashioka (2002) details the benefits of environmental accounting to include: (1) the improvement of corporate image while enhancing environmental consciousness within the company, (2) the reduction of environmental burden, (3) the reduction of environmental costs, (4) the development of environmentally friendly products, and (5) the improvement of environmental decision making.

Kokubu and Nashioka (2002) correlate environmental costs with sales, net income and assets considering only the business area costs, upstream and downstream costs, and management activity costs. They saw the ambiguity of research and development (R&D) costs, social activity costs and environmental damage costs in making the total environmental costs comparable. Using Spearman's correlation coefficient analysis, they concluded that there is positive correlation with non-consolidated data and strong positive correlation for consolidated data. They suggested further studies, given that standardization was taking place at that time, and there was widespread compliance expectation among Japanese companies. Meanwhile, their study revealed certain differences in environmental accounting practices according to company size and industrial sector.

The most recent research relating to Japan was conducted by the Institute for Global Environmental Strategies (IGES). By examining 278 listed companies in Japan from 1999 to 2003, the study reveals that there is a positive effect of corporate environmental activities (using Nikkei Environmental Management Score Report) on financial performance (Tobin's[1] q minus 1 and ROA). However, similar to the findings of Stanwick and Stanwick (2006), the machinery industry appears to show the reverse where higher environmental performance leads to lower financial performance. Interestingly, the positive relationship earlier established in the energy-intensive industry group turns negative as a result of the recent trend of tightening climate policies. While acknowledging the simple correlation to a multiple regression applied in the study of Russo and Fouts (1997), the study advanced the analysis using the Hurlin-Venet extension of the Granger causality test. The results appear to be 'surprising' in the machinery industry considering that it includes household appliance and automobiles (according to the classification of the Ministry of Economy, Trade, and Industry), which are perceived to have excellent environmental records. The study therefore, suggests further examination is needed (Nakao et al. 2005).

In a follow-up study by Nakao et al. (2007), they reaffirm their group's earlier findings that environmental performance has a positive impact on financial performance, and vice versa. Still employing multiple linear regression analysis and Granger causality test on the financial performance of 300 listed companies and Nikkei environmental management survey score, they conclude that the relationship is not just limited to top-scoring firms with regards to financial and environmental performance, but rather a matter of general observation.

Cortez and Cudia (2010) continue the investigations of Kokubu and Nashioka (2001, 2002) as inspired by Nakao et al. (2005, 2007). They reveal that there is a one-way linear relationship between environmental innovations and financial performance (sales, profit, assets) of purposively selected automotive and electronics companies. In a follow-up study, Cortez and Cudia (2011a) explore the concurrent bi-directionality between environmental innovations and financial performance (sales, income, assets, long-term debt, and equity) and how it holds for a longitudinal basis. Long-term debt and equity were included to complete the picture of financial performance analysis. Also relevant is Cortez's (2011a) investigation of evidence from top actively traded manufacturing companies in the Tokyo Stock exchange. Finally, Cortez and Nugroho (2011) surveyed the perception of Japanese

[1] Tobin's q is the ratio between the market value and the replace value of the same asset valued from a financial market perspective.

management on the predominant theoretical perspective between RBV and slack availability of resources in deciding to engage in greening business strategies.

9.3 Hypotheses and Methodology

The broader perspectives of *legitimacy* (Suchman 1995) and *stakeholder theory*; *institutional* and *network theory* (DiMaggio and Powell 1983) are adopted to frame the understanding of the phenomenon of greening businesses. Operationally, the *resource-based view (RBV) perspective* (Barney 2001); *slack availability of resources* (Waddock and Graves 1997; Sharma and Vredenburg 1998); and the *accumulated slack theory* (Cortez 2011a) are used to determine the direction of relationships between the seemingly mutually reinforcing constructs of environmental innovations and financial performance.

This study uses the descriptive and exploratory case study design in comparing eight automotive and ten electronic Japanese manufacturing companies' environmental innovations measured through environmental costs and the related impact on revenues (sales), profitability (income), firm size (assets), accounting risk (long-term debt) and shareholder value (equity).

Toyota and Honda are internationally-leading automotive companies and seem to be the largest in the sample. Including Mazda, Isuzu and Suzuki in the sample allows for variation in company size and product lines. Toshiba and Fujitsu are also globally renowned electronics brands; and to provide for different sized companies, Hitachi, Panasonic, and Sanyo were likewise included in the study.

Following the conceptual theorization and observation work on corporate citizenship and financial performance of Orlitzky (2008), sales and profitability benefits by Senge (2008), cost savings and other income by Porter (2008), and empirical observation covering 1998 to 2001 by Kokubu and Nashioka (2002), we determine environmental innovations (environmental investments plus environmental maintenance costs) as independent variables and sales, income, assets, long-term debt (LTD), and equity as dependent variables.

Environmental innovations in terms of costs include investments and maintenance costs. Environmental investments, regardless of generally accepted accounting principles, include: R&D (otherwise not classifiable as asset); recycling-related investments; other expenses on social contribution; ISO certification; education and training; and investment in plant and equipment (like any tangible asset but pertinent to recycling, prevention of global warming and eco-efficiency).

Maintenance costs include expenses related to environmental measures of waste processing, waste water treatment, atmospheric pollution and environmental preservation. In addition to the maintenance, costs are: awareness building, professional environmental staff and environmental restoration (vehicle recalls, and soil and ground water remediation).

Total environmental innovations (costs) were considered to reconcile the varying treatments of R&D and other discretionary recognition of assets and expenses.

Some companies capitalize R&D into investments while others classify the amount under expenses. This is presumably a result of the differences in interpretation of accounting standards for the recognition of intangible assets or outright expenditure. A number of companies, therefore, simply reported their total environmental costs. Nevertheless, the Japanese guidelines provide for the sum of environmental investments and expenses in the standard environmental or sustainability report.

Suchman's (1995) concept of legitimacy refers to actions of an entity that are "desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definitions". Legitimacy within the context of stakeholder theory suggests the satisfaction of various claims in order to be socially accepted. Japanese companies have grown acutely aware of the environmental disclosure requirements of their various stakeholders as evidenced by the adoption of environmental reporting practices (Stanwick and Stanwick 2006).

Hence, with environmental innovations, the preference of customers or end users of the products are seen to translate into sales. These are currently observable in the sales growth of hybrid cars, the demand for more energy efficient products, and the introduction of a new range of electronics products that have high eco-efficiency rating and provisions for responsible end of life disposal (Cortez and Cudia 2011b). It may be theorized further that environmental innovations create perceived value of automotive and electronics products that customers appreciate and patronize.

H1: Environmental innovations positively impact revenues of Japanese automotive and electronics companies.

The RBV perspective is the most cited theory that explains the link between CSP and financial performance. From Barney's (2001) definition of investments in resources that are "rare, valuable, non-substitutable, and imperfectly inimitable" to achieve an advantage over competition, it has become the backbone of the business rationale for sustainability. Scholars have picked it up and developed the perspective to include the natural resources (Hart 1995); intangible assets e.g. innovation, human capital, reputation, and culture (Surroca et al. 2010); and environmental performance that leads to enhanced profitability (Russo and Fouts 1997). Therefore, the RBV perspective justifies the allocation of corporate resources for greening businesses, develops close relationships with multiple stakeholders, and eventually enhances financial performance (Cortez and Nugroho 2011).

Sustainability is a broader idea that covers life cycle assessment and resource productivity. Accordingly, resource productivity is the process of maximizing the output of a unit resource through improved product designs, efficient production processes and renewal of resources that result in cost savings or opportunities for earning other income.

Earlier espoused by Porter (2008), Senge (2008) and Orlitzky (2008), profitability could result from significant cost savings (Klassen and McLaughlin 1996) through investment in environmental innovations; and other income from renewable and recyclable materials (Cortez 2011b). Therefore, we hypothesize:

H2: Environmental innovations positively impact profitability of Japanese automotive and electronics companies.

As early as 1984, Cochran and Wood highlighted that CSR is most strongly correlated with asset age. Firms with older assets have lower CSR ratings. However, sales growth and profitability accumulated over the years and investments in environmental innovations (facilities and research and development) all contribute to a company's financial position. It is in the light that we investigate the impact of environmental innovations on total assets of a company. Christmann (2000) suggests that complementary assets are required to gain competitive advantage in environmental management. Competitive advantage can be seen through growth in firm size measured in assets. We therefore hypothesize:

H3: Environmental innovations positively impact assets of Japanese automotive and electronics companies, thus increasing firm size.

Following stakeholder theory and RBV, we then examine if shareholder value is maximized through investments in environmental innovations. Increases in stockholders' equity suggest that their stakes are protected alongside with the satisfaction of various claims. The increases in stockholders' proportion in the accounting equation have corresponding decreases in liabilities. McGuire et al. (1988) use liabilities in measuring accounting risk. The idea is that as a company engages in environmental innovations, it should be able to avoid contingent liabilities (Shrivastava 1995; Klassen and McLaughlin 1996) such as expensive clean up costs, environmental fines and litigation. Hence, we hypothesize:

H4: Environmental innovations positively impact shareholder value and negatively impact accounting risks of Japanese automotive and electronics companies.

Alternatively, the slack availability of resources assumes a more realistic view on how and why companies adopt a greening strategy. The theory suggests better corporate financial performance will lead to more available resources to be allocated and invested into CSR activities (Ullman 1985); and more specifically perform environmental innovations (Cortez and Cudia 2011a, b). It allows a company to develop new intangible assets that become the sources of competitive advantages (Sharma and Vredenburg 1998).

We hypothesize that firms with successful financial performance may engage in further environmental innovations, and likewise, less profitable firms may be less willing to undertake socially responsible actions. We theorize that financial performance measured in revenues (sales) profitability (net income), firm size (assets), shareholder wealth maximization (stockholders' equity) and accounting risk minimization (long-term debt) provides slack resources for environmental innovations.

H5: Financial performance in prior years impacts environmental innovations of Japanese automotive and electronic companies.

To verify the above hypotheses, we use panel data regression of financial performance information for eight automotive and ten electronics Japanese manufacturing firms listed in the Tokyo Stock Exchange from 2001 to 2010 specifically generated using the Business Insight COMPUSTAT database. Different panel data regressions verify the impact of environmental innovation as an exogenous variable on revenue, profitability, firm size, accounting risk, and shareholder value as endogenous variables. Another panel regression is also used to verify the effects of financial performance through the five measures on further investments on environmental innovations.

Finally, the RBV perspective and the slack availability of resources are connected into a cohesive theory called the accumulated slack theory, i.e. the two-way direction of relationships of environmental innovations and financial performance affects both the tangible and intangible benefits over time realized by management from corporate social and environmental performance (Cortez 2011a). The first direction, i.e. environmental innovations affecting financial performance has a stronger impact than the other way around (Cortez and Cudia 2011a). The virtuous cycles between these constructs are spun off by the slack availability of resources and positively reinforced by the RBV perspective with the benefits outweighing the costs and the residuals, henceforth accumulating (Cortez 2011a). This concept could be traced back to the perspectives of *good management theory* (Waddock and Graves 1997); and the *enlightened self-interest* model described as an objective effort to rationalize corporate social investment (Wallich and McGowan 1970).

However, Nelling and Webb (2009) cautions that virtuous cycles appear much weaker than previously thought and that CSR could be driven by other unobservable firm characteristics rather than financial performance.

To confirm whether the virtuous cycle between environmental innovations and financial performance exists, a Granger causality test is performed for both directions of the relationship of the variables. This determines whether or not there is a bi-directional relationship of environmental innovation and financial performance, although MOE guidelines simply aim to correlate the two constructs.

9.4 Results and Discussions

9.4.1 The Impact of Environmental Innovations on Financial Performance

In line with the RBV perspective, five sets of panel regressions per industry were used for this first direction and the estimation results are summarized as follows (Table 9.1):

As it turns out for Japan's automotive industry, the relationships for all indicators except LTD are in line with a-priori expectations, thus confirming the hypothesis that sales, net income, assets and equity are being positively affected by environmental innovations. However, the a-priori sign for the impact of environmental innovations on LTD goes against expectations, and given that estimates are all significant, leads us to speculate that companies, regardless of firm size, use long-term debt to finance environmental innovations.

Table 9.1 Environmental innovations impacts financial performance

Independent variable: Environmental innovations (cost)				
Dependent	Coefficient	t	p > |t|	Adj. R-squared
Automotive				
Sales	63.1715	18.72	0.0000	0.9888
Income	6.347892	21.64	0.0000	0.9817
Assets	79.47195	16.82	0.0000	0.9876
Long-term debt	16.69036	19.03	0.0000	0.9887
Equity	27.45368	15.79	0.0000	0.9980
Electronics				
Sales	28.97502	6.16	0.0000	0.9763
Income	−0.8360371	−0.54	0.5880	0.2747
Assets	−0.6067324	−0.13	0.8970	0.9773
Long-term debt	−4.477066	−3.42	0.0010	0.9197
Equity	0.7500055	0.26	0.7970	0.9328

Level of significance = 5%; heteroskedasticity = 0.000; autocorrelation = 0

The electronics industry on the other hand shows very different estimates compared to that of the automotive industry. As it appears, only sales and LTD have significant relationships with environmental innovations that are in line with a-priori expectations, and apparently, environmental innovations have no significant impact on income, assets and equity (Cortez and Cudia 2011b). Therefore, only the hypotheses for sales and LTD are accepted, and the hypotheses for income, assets and equity are rejected. Consistent with the perspective on legitimacy and stakeholder theory these findings suggest that customers of electronics companies patronize the products for their environmental qualities.

The RBV perspective applies in translating internal capabilities into tangible measures of revenue generated for Japanese automotive and electronics manufacturers. The more revealing finding for electronics is on the significant negative impact of environmental innovations on LTD. This shows that electronics greening businesses engage in environmental innovations with the objective of minimizing accounting risks measured in LTD.

9.4.2 The Impact of Financial Performance on Environmental Innovations

From the slack availability of resources perspective, the reverse direction of the previous relationship, namely the impact of prior years' financial performance on environmental innovations was determined using the same data set and panel regression. Five panel regressions per industry were employed to establish the

Table 9.2 Financial performance impacts environmental innovations

Dependent variable: environmental innovations (cost)				
Independent	Coefficient	t	p > |t|	Adj. R-squared
Automotive				
Sales	0.01368	18.72	0.0000	0.9816
Income	0.11323	21.64	0.0000	0.9857
Assets	0.01054	16.82	0.0000	0.9779
Long-term debt	0.05205	19.08	0.0000	0.9822
Equity	0.29844	15.79	0.0000	0.9754
Electronics				
Sales	0.11186	6.16	0.0000	0.9145
Income	−0.00446	−0.54	0.5880	0.8740
Assets	−0.00035	−0.13	0.8970	0.8736
Long-term debt	−0.02884	−3.42	0.0010	0.8899
Equity	0.00112	0.26	0.7970	0.8737

Level of significance = 5%; heteroskedasticity = 0.000; autocorrelation = 0

relationship posited by the fifth hypothesis, and the results are summarized as follows (Table 9.2):

The slack availability of resources postulates that successful financial performance facilitates investments in CSP, and accordingly, unsuccessful operations may limit CSP activities. For the automotive industry, all indicators except LTD confirm the fifth hypothesis that financial performance impacts environmental innovations as displayed by the significant p-values of the estimates. The result of the coefficient for LTD goes against expectations that long-term liabilities decrease environmental innovations, thus justifying the possibility that firms use debt to finance environmental innovations.

On the other hand, the results for the electronics industry seem to mirror the findings of the first direction of construct relationship. The relationship of financial performance and environmental innovations only seem to hold with sales and LTD which are the only significant estimates with consistent a-priori signs. These findings dictate that revenue generation encourages greening businesses to invest in reputation management by engaging in environmental innovations; and that the impact of LTD on environmental innovations reaffirms management learning of the possibilities of risk reduction.

9.4.3 The Virtuous Cycle

The Granger causality tests reveal that majority of the greening businesses for both the automotive and electronics industries only have a single directional relationship. The virtuous cycle appears to be broken for most companies yet two single directions of causality are observable, thus confirming the earlier propositions by Nelling and Webb (2009).

Table 9.3 Granger causality for automotive companies

Granger causality test	Daihatsu	Subaru	Honda	Hino	Isuzu	Mazda	Suzuki	Toyota
Environmental innovations affect sales	○	×	×	○	○	○	○	○
Sales affect environmental innovations	×	○	○	×	○	○	○	○
Environmental innovations affect income	○	×	×	○	○	○	○	○
Income affects environmental innovations	○	○	×	×	×	○	○	○
Environmental innovations affect assets	○	○	×	×	○	×	○	○
Assets affect environmental innovations		○	×	○	○	○	○	○
Environmental innovations affect LTD	×	×	○	○	○	○	○	○
LTD affects environmental innovations	×	×	○	○	○	○	○	○
Environmental innovations affect equity	○	×	×	○	○	×	○	○
Equity affects environmental innovations	×	○	○	○	×	○	○	○

Majority of the single directional relationships between environmental innovations and financial performance are observable in the automotive companies but virtuous cycles pertain only to specific variables (sales, income, assets, LTD and equity). Therefore, these results need to be disaggregated according to the measure of financial performance (Table 9.3).

There is a great variation in the line of causality for all eight automotive companies and it seems that most of them have broken cycles. Notably, Suzuki, a relatively small firm, and Toyota, a large firm, exhibit the full virtuous cycle for all indicators, implying that they adopt both the RBV and slack availability of resources perspective in their greening strategies.

With respect to the indicators, it is the relationship between LTD and environmental costs that has the greatest number of completed virtuous cycles among the observations. The virtuous cycle may not be exclusively driven by revenues, income, firm size or equity, and the incidences of the virtuous cycles in LTD and environmental innovations further reinforce the claim that firms utilize debt financing to afford product and process improvements as reported by regression results.

The findings also suggest that firms do not have to be large into order to exhibit virtuous cycles and or fully benefit from green growth strategies. Small firms, however, may be financially constrained, or may not yet have reached the firm size threshold described by Morhardt (2009) when sustainability activities start becoming independent.

The management perception survey by Cortez and Nugroho (2011) further substantiates the break in the virtuous cycles. The management of automotive companies may appreciate the RBV, i.e. environmental innovations having a positive impact on financial performance, but only as far as sales, profit, and shareholder wealth maximization are concerned. They presumably have attained the firm size threshold Morhardt (2009) points out; therefore their assets, as a matter of perception, are no longer significantly related to their environmental innovations.

On the other hand, automotive companies appear to have more perception responses that are supportive of the slack availability of resources, i.e. financial performance determines decisions to invest in environmental innovations. This could be seen as consistent with the *enlightened self-interest* model (Wallich and McGowan 1970). However, considering the favourable financial performance of automotive companies in the last 10 years, the *accumulated slack theory* (Cortez 2011a) may provide the perspective that benefits have been felt and summed up. What could have started with compliance to regulations and the use of slack resources, reinforced by investments in environmental innovations could have enticed management into thinking that the virtuous cycles are yielding benefits. Orlitzky (2008) refers to this as the *noblesse oblige* or normative view – a sense of obligation to give back to the community arises out of a consistent track record of organizational success (Table 9.4).

Observations on virtuous cycles for electronics firms did not even account for the majority of firms. However, findings point to the causal relationship between environmental innovations and LTD that mutually reinforce each other. Consistent with the earlier methods of panel regression and perception survey (Cortez and Nugroho 2011), LTD appears to be the most significant variable that needs to be examined thoroughly in conjunction with environmental innovations.

Comparing across companies, the companies with the greatest number of virtuous cycles of the indicators are Canon, Casio and Sharp (which have 4 out of 5 cycles) followed by Fujitsu, Hitachi and Panasonic (which have 3 out of 5 cycles). The rest of the interpretation for Granger causality could yield more meaning on a per company basis and not within the context of a panel data regression analysis. There may be other random effects or causal mechanisms that are firm specific and unobserved that lead to the causality results on a per company basis. Regression results show income, assets and equity having no significant relationships with environmental innovations and vice versa.

Electronics companies have not yet recovered economically from their turn of the century financial performance levels which have been worsened by the recent global crisis. The perception survey reveals that there is no clear support for the first direction of constructs relationship, i.e. environmental innovations affecting financial performance. However, management of electronics companies perceive increased sales, improved profitability, enhanced asset size, and maximized shareholder wealth as determining factors for investments in environmental innovations. Most importantly, the overall consensus is that risk is minimized. Therefore, the slack availability of resources is their predominant perspective. While perception

Table 9.4 Granger causality for electronics companies

Granger causality test	Canon	Casio	Fujitsu	Hitachi	JVC Kenwood	OKI Electric	Panasonic	Sanyo	Sharp	Toshiba
Environmental innovations affect sales	○	○	○	○	×	×	○	○	○	×
Sales affect environmental innovations	○	○	×	×	○	○	×	×	○	○
Environmental innovations affect income	○	○	×	×	○	○	○	○	○	×
Income affects environmental innovations	×	○	○	○	×	○	×	×	○	×
Environmental innovations affect assets	○	○	○	×	○	×	○	×	○	×
Assets affect environmental innovations	○	○	○	○	○	○	○	×	×	○
Environmental innovations affect LTD	○	○	○	○	○	×	○	○	○	○
LTD affects environmental innovations	○	○	○	○	○	×	○	○	○	○
Environmental innovations affect equity	○	○	○	○	○	×	○	×	○	×
Equity affects environmental innovations	○	×	○	○	×	○	○	×	○	×

somehow deviates from empirical evidence, considering the situation of the electronics companies, they could have performed much worse financially had they not engaged in greening strategies through environmental innovations.

9.5 Conclusion and Recommendation

Statistical tests using panel regression analysis reveal that environmental innovations have a linear relationship with the financial performance of Japanese firms included in the study. This might imply that any change in the environmental innovations made by the companies would result to a corresponding level of change in their sales, net income, assets, long-term debt and equity, *ceteris paribus*.

While having a weaker coefficient, there is a reverse relationship between environmental innovations and financial performance following the slack availability of resources perspective.

Considering the first direction, i.e. the impact of environmental innovations on financial performance in the automotive industry, all relationships are significant and according to a-priori sign except for long-term debt. Environmental innovation particularly increases sales, net income, assets and equity, but counter-intuitively increases long-term debt. The reverse direction of the relationship similarly yields the same results with a simple change in the magnitude of the marginal contribution of environmental innovation to the financial performance indicators. Similarly, all relationships hold except for long-term debt which is still counter-intuitive, however significant. The Granger causality test shows that not all companies show the virtuous cycle.

The results for the electronics companies show a stark contrast. Environmental innovations have a significant impact only on sales and LTD with the signs according to expectations. While investments in environmental innovations increase sales and decrease LTD, it has no significant relationship with profitability, firm size and equity. The reverse direction of the relationship mirrors the results of the first direction regarding significance as well as relation of signage to theoretical expectations. The Granger causality test shows great variation across observations. There may be unobserved heterogeneity across firms when it comes to the causality of environmental innovations and financial performance.

There is much to learn from the Japanese environmental reporting, particularly with regards to how regulation plays a central role in promoting sustainability. While these reports involve an estimation and adjustment process from generally accepted accounting principles based annual financial reports, readers and stakeholders must exercise discretion in interpreting the benefits of green growth strategies.

With a decade of comparable information, further studies that could emerge from the above findings may include the impact of environmental innovations on financial markets particularly market value. It would likewise be interesting to replicate this study in other capital markets.

Comparative studies within the MNE would also be a potent ground for research. The samples in this study covered the global headquarters in Japan and their consolidated reports. Studying their subsidiaries using the same variables may be interesting considering that they belong to the same extended value system.

As in the case of all sustainability studies, it is recommended that research pursue continuous investigations on longitudinal effects of the relationships of constructs while examining various ways of operationalizing sustainability according to the appreciation of the various stakeholders of companies.

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Chapter 10
Achieving Greener Growth: A Business Perspective for Proactive Commitment

Fabien Martinez, Diego A. Vazquez-Brust, Ken Peattie, and Keivan Zokaei

Abstract This chapter looks at how green-growth policy can be translated into business practice. Following 'cradle-to-cradle' and the 'natural steps' perspectives, it contends that 'greening the business' can add value to existing business models via the symbiotic pursuit of green values and lean production practices (the so-called "Green and Lean" paradigm). A framework is presented – drawing on the contingency theory – to suggest basic requirements for successful symbiotic 'green and lean' relationships. The model proposes that a sustainable corporate action plan, enabling a strategic orientation of lean and green decision-making, draws upon five interrelated dynamic contingencies: corporate values, consumption, business benefits, legislation, and technology. The theoretical propositions are illustrated and extended using the case study of Adnams Brewery (Southwold, UK) – a company that has come to symbolise the benefits of adopting strong eco-friendly values to 'green' the business and its products. In particular, the company is effectively exploiting marketing opportunities – through a "strong brand and growing reputation" – and enhancing productivity.

Keywords Contingency theory • Corporate values • Environmental and social responsibility • Lean and green

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10.1 Introduction

Hawken et al. (2002) warn about Manufacturing processes representing by far the greatest source of environmental degradation, due to the often invisible, 'taken for granted' material flows and inherent waste that are manifested in everyday industrial or consumption activities. As the negative impact of business activities on society intensifies, the Organisation for Economic Cooperation and Development (OECD 2011) advocates 'greener growth' strategies. The 'green growth' agenda prescribes the harmonisation of economic growth, competitiveness and environmental sustainability (OECD 2011). To achieve this goal and transit to a green economy, corporate responsiveness towards 'green' issues needs improvement and purposeful alignment with competitiveness (Braungart and McDonough 2008; OECD 2011). Although the OECD (2011) concedes that an increasing number of companies are effectively responding to the challenges and opportunities of moving towards a low-carbon economy, the organisation echoes Braungart and McDonough's (2008) call for further progress and transformation to an eco-effective vision. Accrued stakeholders' diligence on business societal performance (Zadek 2004) and reinforced regulatory framework may in fact encourage more companies to embark into the transition to green economy (OECD 2011). The 'green growth' message of inclusive sustainable development links back to the work of Drucker (1974) whose approach to management tasks, responsibilities and practices contends that the aspiration of business leaders should be to convert society's needs into opportunities for profitable business without compromising the need of future generations. That is, "it is not enough for the business to provide just any economic goods and services; it must provide better and more economic ones. It is not necessary for a business to grow bigger; but it is necessary that it constantly grows better" (Drucker 1954, p. 34).

The aim of this chapter is to discuss how businesses may contribute to consolidate the 'green growth' agenda. We draw upon existing research to discuss the integration of Environmental Social Responsibility (henceforth, ESR) activities into business operations and strategies. In essence, the study seeks to address the following research question: how can firms, within their specific context, achieve harmonisation between ESR and economic performance, thus effectively supporting the 'green growth' agenda? We provide empirical evidence on how Adnams Brewery (Southwold, UK) implemented ESR strategies with corporate values and technological excellence as key drivers. The research combines secondary data (corporate reports) and primary data (face-to-face qualitative interviews with Adnams' MD and discussions with employees) to illustrate/extend the theoretical framework.

10.2 Theoretical Framework

Below, in Sect. 10.2.1, we build on the literature addressing the topics of ESR and Corporate Social Responsibility (CSR) to comprehend the challenges facing businesses of how to address social and environmental issues without compromising financial stability – i.e. reducing production cost and exploiting marketing opportunities. This leads to reflection on the compatibility between lean and green. Subsequently in Sect. 10.2.2 four stages of ‘maturity’ are identified: trade-off, ambidexterity, synergy and symbiosis – each of which can be seen to lead progressively towards a more developed contribution to a Green Growth economic model.

We conclude the theoretical framework in Sect. 10.2.3 by proposing a sustainable action plan embracing five dynamic contingencies – i.e. consumption, business benefits, technology, legislation and corporate values. Responding effectively to these contingencies is argued to be essential in the pursuit of symbiotic compatibility between *lean and green*.

10.2.1 Making a Business Case for ESR Investment: Entrepreneurship and Ethical Differentiation

There is a widely accepted view that CSR/ESR and goals of profit maximisation are compatible (inter alia, Orlitsky et al. 2003; Porter and Kramer 2002; Siegel 2009) but this argument has often been raised rather uncritically. There is another school of thought, principally influenced by the work of Milton Friedman, that the two objectives are fundamentally incompatible (e.g., Dienhart 2008; Margolis and Elfenbein 2008).

Devinney (2009) refutes the idea that corporations can be truly socially responsible because they have conflicting virtues and vices. The pursuit of immediate profits and pressures for productivity improvement in industrial operations often conflict with engagement in purely philanthropic environmental or social activities. Managers of publicly traded firms, Siegel (2009) explains, have a fiduciary responsibility to adopt ‘green management’ practices only if such actions complement the organisation’s business and corporate-level strategies. The decision-making process regarding ESR initiatives is to be opportunistically and strategically oriented, with a view to generating tangible returns to the firm (Peloza 2006; Siegel 2009) and provoking a simultaneous advancement of corporate and environmental goals (Siegel 2009). ESR or CSR are viable only to the extent that corporations see some ‘payoff’ to their investment (Devinney 2009). Devinney comments:

> *“...the holy grail of CSR* [often used interchangeably with ESR] – *‘doing well by doing good’ – is an illusory goal that is noble in spirit but unachievable in practice...Corporations can be made more ‘virtuous’ on some dimensions, but this will invariably involve a price on other dimensions”* (2009, pp. 45–46).

As a practical illustration, it has long been assumed that environmental initiatives can arguably reduce a firm’s (immediate) profitability (King and Lenox 2001a); and conversely, the quest for short term economic performance often discourages ‘peripheral’ eco-friendly activities. Yet, businesses are confronted with the challenge of simultaneously and ‘ambidextrously’ creating value through the economically productive use of resources and making bold adaptations to promote environmentally and socially sustainable actions (Kollman and Stockman 2008; Porter and Kramer 2002). In other words, managers should seek to directly link enterprise sustainability to the creation of shareholder value (Hart and Milstein 2003); and therefore, should aim for a ‘syncretic’ ESR model which reconciles supposedly divergent objectives (Kollman and Stockman 2008) and enhances both the firm’s competitiveness and its broader societal position (Porter and Kramer 2002).

An economic analysis of ESR begins with the realisation that such activities have emerged in response to the perception of a market failure; that is, instances where there is a divergence between the private and social costs of a firms’ actions.[1] It follows that eco-efficient firms gain the competence to constantly spot excess and develop alternative processes to trigger the reduction or removal of external costs identified by Siegel (2009). This process requires the implementation of practices of entrepreneurship whereby a firm manages to discover, evaluate and exploit the economic opportunities present in market imperfections hindering sustainable development (Vazquez-Brust et al. 2009). For instance, Siegel (2009) reports the efforts of Wal-Mart and British Petroleum (BP) to reduce pollution (partly through the reduction of greenhouse gas emissions) while enhancing their profitability. The wider achievement of syncretism between ESR and economic objectives is subject to the development of an industrial transformation enabling society to create a vital economy that uses radically less material and energy (Hawken et al. 2002) and rewards green business entrepreneurship.

Entrepreneurial pursuit of a syncretic equilibrium can further translate into competiveness through ethical differentiation. Ethical differentiation refers to marketing opportunities and strategies of product differentiation that either signal superior ethical virtuosity (Siegel and Vitaliano 2007) – as in the case of vertical differentiation, e.g. given the same characteristics/features, consumers would prefer to own a more fuel-efficient vehicle (Siegel 2009) – or appeal to specific consumer’s tastes, beliefs – as in the case of horizontal differentiation, e.g. consumer choice of brand is based on superior environmental performance (Siegel 2009). ESR can generate consumer loyalty and other benefits that are uniquely valuable to the company (Porter and Kramer 2002). Benefits that may arise from ESR include product differentiation, reputation/image enhancement, and improved relations with workers, customers, suppliers, government, and the community (Siegel 2009).

ESR can thus constitute a marketing tool (a sub-category of product differentiation) using *ethical differentiation* to signal a hierarchy of perceived product/service

[1] The societal cost is defined as the private cost to the company plus an additional external cost generated by the production and delivery of a good or service that is not incurred by the producer, e.g. pollution and environmental degradation such as global warming, acid rain, and deforestation (Siegel 2009).

virtuousness. The connecting tissue between ethical differentiation and entrepreneurship is leadership. An increasing number of business owners and managers are actually transforming their enterprises to become more environmentally responsible because of deeply rooted beliefs and values (Bénabout and Tirole 2010; Hawken et al. 2002; Waldman et al. 2006). In turn, organisations with inspiring, transformational leaders, possessing strong values, tend to have superior social performance which can well be mirrored in financial returns (Sully de Luque et al. 2008).

Therefore, the adoption of ESR is understood in this paper as a strategic choice that is not exclusively motivated by macro-level (inter alia, population, production, distribution, regulation) and meso-level forces (institutional domains and corporate units) but also embrace micro (individual) level influences – inter alia, cognition, emotions, values, roles, status, demographic (Bansal and Gao 2006; Turner and Daily 2008; Waldman et al. 2006).

10.2.2 The Four Stages of Compatibility Between Lean and Green

This transformation towards syncretic business operation is believed by a number of authors (inter alia; Gustashaw and Hall 2008; King and Lenox 2001b; Simons and Mason 2003; Wehrmeyer et al. 2009) to occur via the adoption of lean thinking; which provides a generic framework that helps to continuously identify critical areas of potential improvement (Hicks 2007); and in particular in the area of environmental performance.

The relation between lean and green however, remains understudied. In order to advance understanding, we draw now upon existing research to pose the assumption that lean may be associated with green in various ways. Such ways may represent subsequent stages in an evolutionary process of organisational 'leaning and greening'. This is reflected in Fig. 10.1 as four stages of compatibility between lean and green which we label as trade-off (Hahn et al. 2010; Porter and van der Linde 1995), ambidexterity (Aupperle et al. 1985; Kollman and Stockman 2008; McNulty and Davis 2010), synergy (Ambec and Lanoie 2008; Dowell et al. 2000; Orlitsky et al. 2003; Salama 2005), and symbiosis (King and Lenox 2001a, b; Porter and van der Linde 1995; Schaltegger and Figge 2000; Siegel 2009).

Trade-off exists when lean and green become mutually inhibitive instead of reinforcing one another. Ambidexterity is the state of being equally adept in the advancement of lean production practices and environmental performance, one complementing and/or adding to the other without significant correlation. Synergy consists of a catalytic effect between lean and green in a mutually beneficial relationship. Finally, symbiosis is proposed, notably by King and Lenox (2001b), to represent the most advanced stage of compatibility between lean and green. At this final stage, a relation of interdependency is inferred and this model is viewed as the most appropriate state for business to contribute to a Green Growth

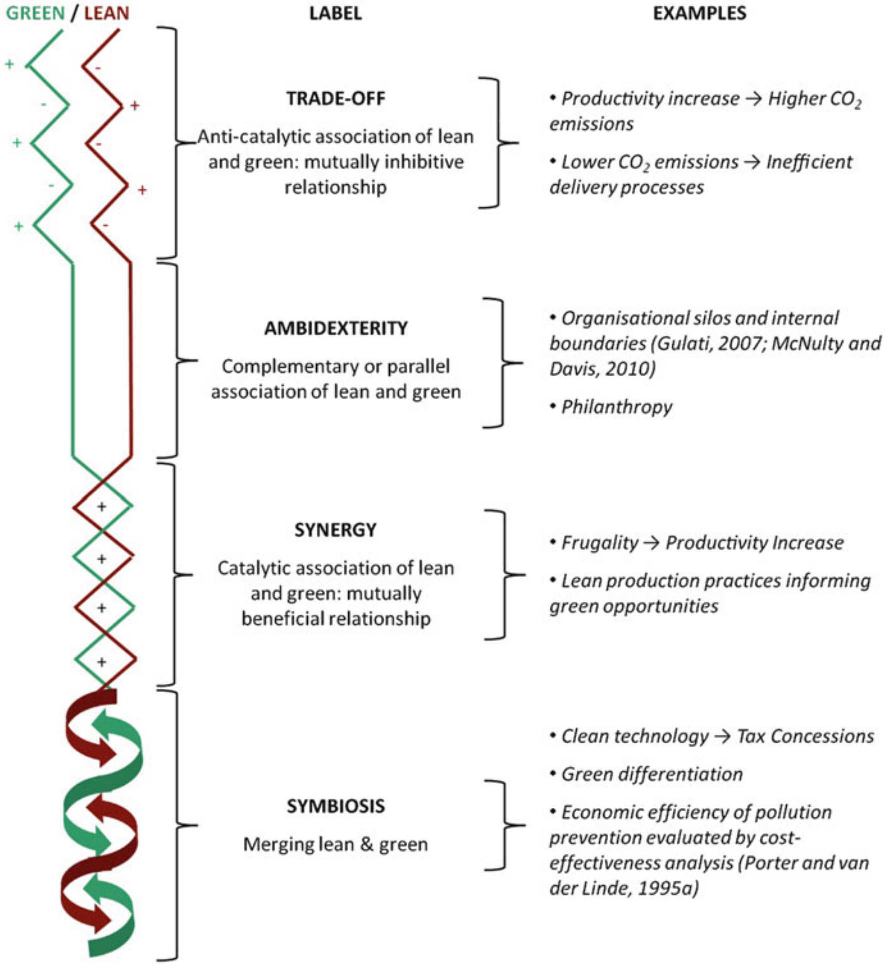

Fig. 10.1 Framing lean and green performance; the four stages of lean/green: trade-off, ambidexterity, synergy, and symbiosis

economy: the symbiotic compatibility of green and operational effectiveness and efficiency (abbreviated herein as EFF^2). Figure 10.1 sketches these stages and attaches examples, notably extracted from Gulati (2007) and Porter and van der Linde (1995).

In using this framework as a diagnostic or mapping tool for evaluating green against lean, the wider economic consequences of strategic and operational decisions or change may be more effectively appreciated. The argument now extends to discuss the dynamic contingencies to be considered for the planning of ESR integration and the pursuit of lean/green symbiosis.

10.2.3 Planning Lean and Green: The Four System Conditions and the Five Dynamic Contingencies

The Natural Step and the four system conditions of Robèrt (2002) are put forward as fundamental basis to guide organisational 'greening' processes. These are complemented by a sustainable action plan embracing five dynamic contingencies – consumption, business benefits, legislation, technology and corporate values – proposed as a strategy to successfully associating lean with green, thereby achieving syncretic equilibrium of ESR with economic performance.

10.2.3.1 The Natural Step and the Four System Conditions

In 'the Natural Step story', Robèrt (2002, p. 64) advocates compliance with a set of principles to be followed –"*the four System Conditions*" – in order to achieve sustainability. These principles imply four suggested practices based on what are assumed to be the conditions for a sustainable society: (1) "*substitute certain materials that are scarce in nature with others that are more abundant, use all mined materials efficiently, and systematically reduce dependence on fossil fuels*"; (2) *"systematically substitute certain persistent and unnatural compounds with ones that are normally abundant or that break down more easily in nature, and use all substances produced by society efficiently"*; (3) "*draw resources only from well-managed ecosystems, systematically pursue the most productive and efficient use both of those resources and of land, and exercise caution in all kinds of modifications in nature"*; (4) finally *"use all of our resources efficiently, fairly, and responsibly so that the needs of all people on whom we have an impact now and the future needs of those not yet born stand the best chance of being met*."

The Natural Step perspective has influenced one of the management approaches more closely related to green-growth ideas: 'Cradle-to-cradle' industrial design (McDonough and Braungart 2002). The goal here is to positively select and exploit the ingredients from which a product is made, and how they are combined. Substances such as PVC, cadmium, lead, and mercury are known to be bioaccumulative and to cause such obvious harm that getting free of them is almost always a productive step (McDonough and Braungart 2002).

Robèrt (2002) emphasises that the success of the natural steps approaches relies upon the development of favourable conditions for individual creativity within the organisation. This can be achieved by involving key stakeholders including employees and outsourcing collaborators, suppliers, clients, and other partners. Collaboration within supply chains allows for objectives and guidelines to be shared amongst shareholders and a common language to emerge. Robèrt (2002) points to the importance of scientific knowledge to assess the impact of material resources or "*ecological ludicrous substances*" (Robèrt 2002, p. 96) on the ecosystem. Research and development, training and education can therefore be viewed as motors to meso-level (organisational) eco-efficiency; that is, they

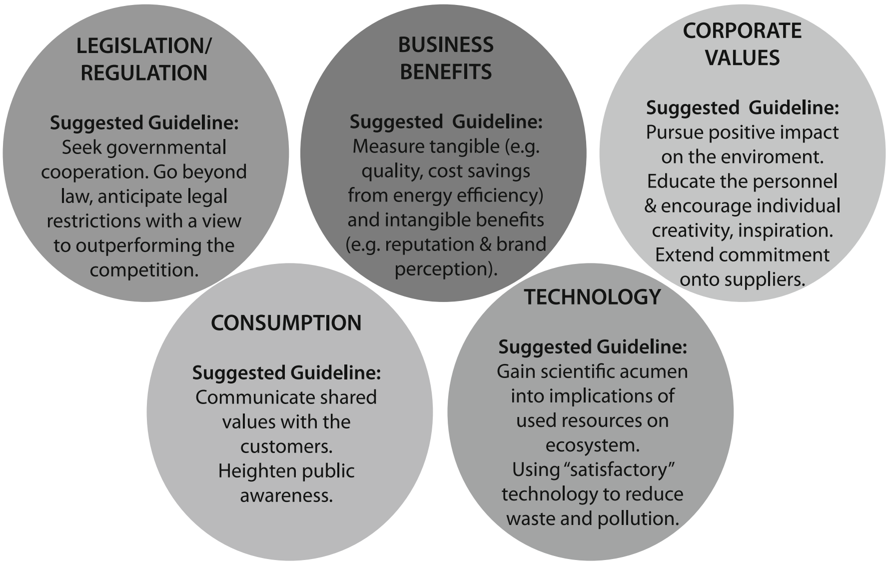

Fig. 10.2 The dynamic contingencies to be considered to design a sustainable business action plan

instigate micro-level (individual) eco-friendly actions in addition to creating in-house scientific expertise on sustainability.

According to Cohen and Winn (2007) and Mc Donough and Braungart (2002), an *ideal* pace of transition is incremental and rigorously controlled with cautious reflections on costs inducement. The holistic achievement of the lean/green association requires delineating strategic 'landmarks' around which businesses can develop constructive responses to operational and environmental pressures.

10.2.3.2 Sustainable Action Plan and Dynamic Contingencies

The system conditions suggested by Robèrt (2002) are integrated into our argument as the underlying principles of a sustainable corporate action plan which, as illustrated in Fig. 10.2, draws attention to five interrelated dynamic contingencies: consumption, business benefits, technology, legislation and corporate values. We use the formulation 'dynamic contingency' to express the varying and evolving nature of consumption, potential for business benefits, technological amenities, regulatory framework and cultural premises around different regions and industries. This falls in line with Donaldson (2008) and the contingency theory (Burns and Stalker 1961) in that we contend that managerial choices of organisational structure and strategy that produce the highest lean/green performance depend on the fit of the structure/strategy to the contingency factors proposed in this section. Each dynamic contingency influences the association of lean/green with the various dimensions that are outlined in the form of suggested guidelines in Fig. 10.2. Hawken et al. (2002) classify the methods to increase industry's energy and material productivity into at least six categories which often reinforce one another: design; new technologies, controls, corporate culture, new processes and saving materials. The following contingency factors embrace all of these categories.

Consumption – A holistic approach to lean and green is to be sought, notably via the promotion of collective actions to address social and environmental concerns (Zadek 2004) thus embracing the consumption end of the supply chain. That is, market knowledge must be gained to enable a firm to align with consumer values and expectations. A *lean*/*green* company must integrate responses to the potential issue of information asymmetry (Cohen and Winn 2007; Siegel 2009) reflecting relative distance with consumers in the way ESR initiatives are perceived by consumers, communicated to consumers and may be misinterpreted or misunderstood at the consumption end of the supply chain. Environmentally conscious, shrewd consumers can significantly reduce environmental emissions by not buying environmental unfriendly products.

Business benefits – Sustainable entrepreneurs are potentially able to identify the opportunities present in market imperfection (Vazquez-Brust et al. 2009) to venture toward the triple bottom line (Cohen and Winn 2007). These opportunities for improvement are present at each stage of the supply chain; in particular, environmental prudence lowers costs in the long run not only for the company, but also for customers and vendors (Cruz 2009). Exploitation of these marketing opportunities can substantially strengthen a firm's competitive position (Bansal and Gao 2006); in particular, continuous improvement strategies (Kaizen methods) can be used as a competitive differentiator both in terms of productivity (i.e. enhanced capabilities) and brand image. Minimising or annihilating company-external and company-internal distribution conflicts (e.g. inefficient flows of materials) can be a shining example to follow (Schaltegger and Figge 2000) as a means to harness the quantitative and qualitative business benefits of *lean*/*green* practices. Quantitative benefits include, inter alia, cost savings from energy efficiency, productivity increases and quality improvements. It is especially important to analyse the potential increase in shareholder value (Schaltegger and Figge 2000) to create a strong motive for management to become actively involved in ESR, thus presenting a strong business case for the association of lean with green (Suh et al. 2005). Qualitative or intangible benefits mainly translate into positive effects on reputation and brand perception (Siegel and Vitaliano 2007). According to Zadek (2004), environmental and social responsibility can generate a competitive edge and contribute to the company's long term success.

Legislation – As tough legislation is being established to enforce environmental responsibility and energy efficiency – especially on UK businesses (Adam 2009) – a pro-active solution may be to seek governmental cooperation to implement sustainable operations throughout the supply chain. For example, McDonough and Braungart (2002) convey the experience of Ford who negotiated with the government to experiment with treating its soil in a new way. Pre-empting legal sanctions and even going beyond the law with pro-active environmental thinking can in turn foster financial performance and competitiveness (Cruz 2009; Zadek 2004); that is, taking the lead in green management practices may obviate the risk of further or higher governmental taxations (e.g. '*la taxe carbone*' in France) or consumer boycotts led by an NGO (Baron and Diermeier 2007). Besides, some companies, Hawken et al. (2002) convey, would only invest in ESR activities to meet regulations – e.g. Nike's ESR commitment is principally driven by the increasing volume of environmental legislation primarily coming out of Europe (Charter 2001, p. 53).

Technology – Internally conceived eco-friendly responses are to be developed to address the scientific implications of business activities on eco-systems notably via the use of satisfactory technologies which reduce waste and pollution. The objective is to acquire and/or develop the capacity to reduce the use of problematic substances or resources and lean toward eco-efficiency and quality excellence through the marketing of products that generate nutritious effects on the environment – e.g. "*cars designed to release positive emissions*" (McDonough and Braungart 2002, p. 179). That is, according to Cohen and Winn (2007), and Cruz (2009), efficient exploitation of technological or scientific resources or uptake of innovation in environmental technologies can generate positive environmental externalities, thus remedying polluted eco-systems to (ideally) enable regenerative ecological capacity which may result in increased species diversity and greater resiliency.

Using innovative technologies is critical to the effective association of lean with green. It amounts to involving everyone within the organisation in eliminating profligacy – i.e. continuous overuse of energy and resources – throughout supply chain processes and alternatively spread the notion of frugality – i.e. being economical in use or expenditure of resources, prudently saving or sparing; not wasteful. A frugal manager/employee may be a sustainable manager/employee who is engaged in dealing responsibly with waste (Hawken et al. 2002). Hawken et al. (2002) advocate the establishment of continuous monitoring methods – in the form of measurement and control intelligence – to enhance the purity of products and production processes. Strategies to reduce carbon footprints also include environmental management systems, waste recycling, implementation of environmental performance measures, sustainable building.,, staff environmental awareness (travel, lights, waste, etc.. . .), product design improvements, and eco-friendly supply chain and water management.. Businesses are increasingly reviewing the energy, materials, and manufacturing systems required to provide the specific product qualities (strength, warmth, structure, protection, function, speed, tension, motion, skin) expected by end users and are turning away from mechanical systems requiring heavy metals, combustion, and petroleum to seek solutions, that use minimal inputs, lower temperatures, and enzymatic reactions (Hawken et al. 2002). This evolution can be referred to as the substitution of conventional raw materials for environmentally friendly materials; a transition which may require heavy expenditure and is therefore difficult to implement (Charter 2001). Some businesses are switching to imitating biological and ecosystem processes through the replication of natural methods of production and engineering to manufacture chemicals, materials, and compounds, and even microprocessors (Hawken et al. 2002). This refers to the concept of biomimicry experimented, for instance, by Nike to develop a combination of learning from nature and utilisation of sophisticated chemistry and science (Charter 2001). The most exciting technological developments have often resulted from emulating nature's life temperature, low-pressure, solar-powered assembly techniques, whose products rival anything human-made.

Corporate values – The fifth and last dynamic contingency influencing the association of lean with green is concerned with business values as the expression of, and commitment to, spiritual principles sealing a set of strategic and behavioural guidelines in daily business activities. Infusing corporate values translating the vision of a sustainable future requires building awareness or 'educating' the personnel – especially front line employees – and encouraging individual creativity, inspiration within the organisation. As to why business organisations are engaging in CSR, Aguilera et al. (2007) and Secchi (2007) argue that corporations are being pressured not just by external actors such as NGOs and the government, but also internal actors like employees. The establishment of a strategic social or philanthropic agenda indicating corporate awareness at the meso level (Aguilera et al. 2007; Holm and Stauning 2002) of its social and environmental impact or its exposition to the influence of wider stakeholders, can therefore emerge not only externally but internally at micro level (Aguilera et al. 2007; Secchi 2007) – through personal convictions or values of individual managers whose pro-social behaviour (Bénabout and Tirole 2010), sensibility and proximity to the cause ultimately determine the possibility of engaging firm's resources. The implication is that corporate values are instilled by business leaders whose charisma and degree of sensitivity or awareness vis-à-vis environmental ills determine the propensity of ESR engagement (Hollender 2004; Martinez and Agüero 2005; Waldman et al. 2006).

The traditional top-down managerial styles may be revised to promote greater worker self-management that delivers more flexibility, productivity and conditions improvement. Employees – especially front line associates – can offer/generate ideas to improve environmental performance. Spreading the notion of frugality – possibly via the three Rs of Reduce, Reuse, and Recycle – permits to minimise waste and emissions from operations, lean toward 'zero landfill' and prevent pollution by focusing everyone's attention on where to get the most advantage from their environmental efforts (Hart and Milstein 2003; Huppes and Ishikawa 2007). Ultimately, this idea of involving all staff can generate substantial cost savings, particularly for manufacturers (Zadek 2004)... Pro-environmental corporate values must be further extended onto suppliers with a view to achieving homogeneity of ethical standards throughout the entire supply chain and 'holistically' coordinate ESR efforts.

Having crystal-clear views on the five aspects[2] sketched in Fig. 10.2 can be viewed as a condition for the simultaneous pursuit of eco-efficiency and economic performance. That is, the decisions of managers should be "*based on the best*

[2] Local climate and infrastructures can be added as constant, relatively foreseeable contingency implying different degrees of adaptation and responses to the dynamic contingencies.

information available to them, and on their aesthetic judgment" (McDonough and Braungart 2002, p. 169). A firm which develops an innovative sustainable action plan can potentially harness the opportunity to put pressure on all of its major competitors (Cohen and Winn 2007) – such was the case of Electrolux (Robèrt 2002) – thereby leading the way to the successful integration of lean and green across the sector. Robèrt (2002) stresses the capacity of businesses to make predictable sense out of the endpoint of sustainability via such a planning technique notably used by IKEA as backcasting – i.e. planning ahead from a starting point of success in the future; in other words, what the firm could do today to get to a successful result envisaged in the future.

Developing strategic, tactical, and operational responses embracing the five dynamic contingencies outlined above arguably allows business managers to develop a range of tools and techniques to evaluate the impact of ESR initiatives on their key objectives – i.e. profit, environment and risk (Cruz 2009) – thereby empowering them to effectively put lean/green approach into practice. Life cycle assessments (LCA) – notably used by Nike (Charter 2001) – are an effective tool to fully understand the impact of managerial decisions from all perspectives – i.e. economical, environmental and social.

10.3 Adnams Case Study

The principal activity of Adnams Brewery is to produce cask ale and pasteurised bottled beers with an annual production of around 85,000 barrels for distribution mainly in East Anglia. The evolution and growth of the company led to the development of diverse business activities. Adnams can now be defined as a brewer, hotelier, wine and kitchenware merchant and owner of 74 non-themed pubs. Moreover, its distribution centre allows or the direct supply of more than a thousand other outlets. Adnams Brewery has come to symbolise the benefits of strong eco-friendly values driving to 'green' the business and its products (e.g. Adnams' carbon-neutral East Green beer) with a view to reducing carbon emissions and combating climate change. The efforts of the company to generate a positive impact on the environment while preserving business interests are discussed. Particular emphasis is placed on the strategy of combining 'pro-ethical' corporate values with technological excellence to ultimately harness substantial business benefits. This strategy not only enabled substantial improvements in terms of environmental performance but generated quantitative and qualitative business benefits, principally in the form of cost savings and brand image enhancement. Drawing on in-site visits, an interview with Andy Wood (Chief Executive), and corporate reports, we explain how Adnams successfully transposed green thinking and the use of eco-efficient technologies into quality, cost and delivery improvements – i.e. a lean approach. However, Adnams' decision makers are to further reflect on how to turn the radical (technological) improvements – achieved via the acquisition of new brewing system and distribution depot – to a long-term sustainable plan with continuous improvement as the driving *philosophy* (Fig. 10.3).

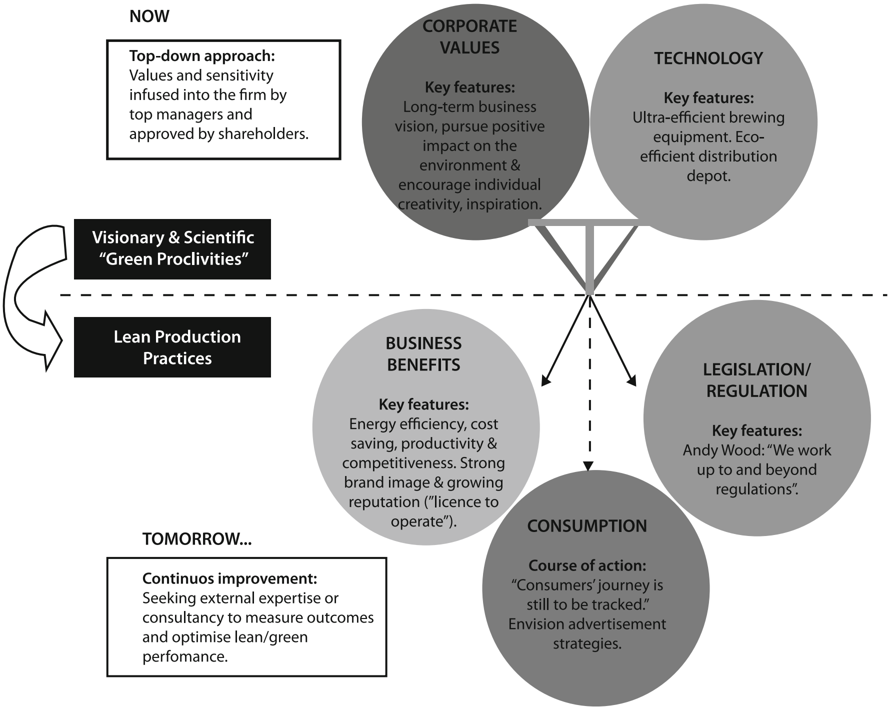

Fig. 10.3 The 'Greening' process at Adnams Brewery

Figure 10.3 is our conceptualisation of the strategy adopted by Adnams to associate the 'greening' of its activities with optimised business performance. Below, we discuss the impact of corporate values (Sect. 10.3.1.1) and technology (Sect. 10.3.1.2) on the progress of the company. Next in Sect. 10.3.2, we put forward the quantitative and qualitative benefits obtained by Adnams as a result of its pro-environmental strategic orientation and recommend future directions to *profitably* push forward the greening process.

10.3.1 The Greening Process and Related Benefits

10.3.1.1 The Ethos of Adnams' Inspirational Leaders and Full Adherence of Staff

Adnams Brewery is an innovative company that dares to initiate changes and where top managers have a strong ethos about how the company should behave and improve its green credentials – and hence seek to be a reference in corporate responsibility. Adnams' Chief Executive Office (CEO), Dr. Andy Wood, has been instrumental in leading Adnams in a transformational and distributed fashion into one of the most environmentally-proactive brewers in the UK. A top-down approach is prescribed with the fundamental role of inspirational leaders who express clear values to determine the business route to social and environmental responsibility. This falls in line with Hollender (2004) who advocates the need to be clear about what are the values of the company prior to bringing environmentally and socially responsible goals to life. In Adnams, these values are constructed within the organisation, have a collective approbation, and most essentially emanate from the top management and are supported by shareholders. They concretely translate into a collective momentum of social and environmental sensitivity within the firm which, in turn, transpires into adherence of staff; for instance, employees are reported to be competitive in becoming the 'environmental super-hero' of the firm by spotting areas of improvement and proposing best alternatives.

Adnams' decision-makers can be defined as transformational leaders (Waldman et al. 2006) who possess the boldness and inspirations to make environmentally and economically sensible changes. The firm is in fact committed to paying close attention to the environmental impact of its operations through the association of social and business benefits with long-term sustainable success.

According to Adnams MD, the business route of Adnams is prevalently determined by the vision of a long-term, sustainable future. Although the economic viability of eco-friendly initiatives is not omitted, ESR actions are not essentially validated by immediate cost-benefit analysis.

Long-term strategic orientation, the continuous pursuit of positive impact on its environment and its inclination to encourage individual creativity, inspirations are the key features of Adnams' ethos. What Andy Wood refers to as "*enlightened self-interest*" led Adnams to take a different path and create greater value, which translates into competitive distinction. The association of applied pro-ethical values with the quest for technological excellence lead to an effective symbiosis of lean production practices and visionary 'green proclivities', as it was illustrated in Fig. 10.3, above.

10.3.1.2 Technological Excellence for a Radical *Green Transition*

The radical green transition enabled was enabled by scientific 'green proclivities' that translated into the acquisition of ultra-efficient technologies in the installation of an innovative brewing system and state-of-the-art, eco-efficient distribution depot. Together, these innovative actions resulted in substantial reduction of waste and enhancement of productivity via a more efficient delivery of operational effectiveness. Figure 10.4 illustrates savings in CO_2 emissions in the brewing process (19%), transport (20%), bottling process (18%), and bottle manufacture (34%) of East Green beer.

On a more qualitative note, Adnams' efforts to invest in new technologies positively influenced its relationships with the wider stakeholders, including, inter alia, the local community, governmental institutions, customers and consumers. In fact, various stakeholders were, and still are, incorporated into the process of innovation; e.g. Cambridge University, the University of East Anglia and local associations.

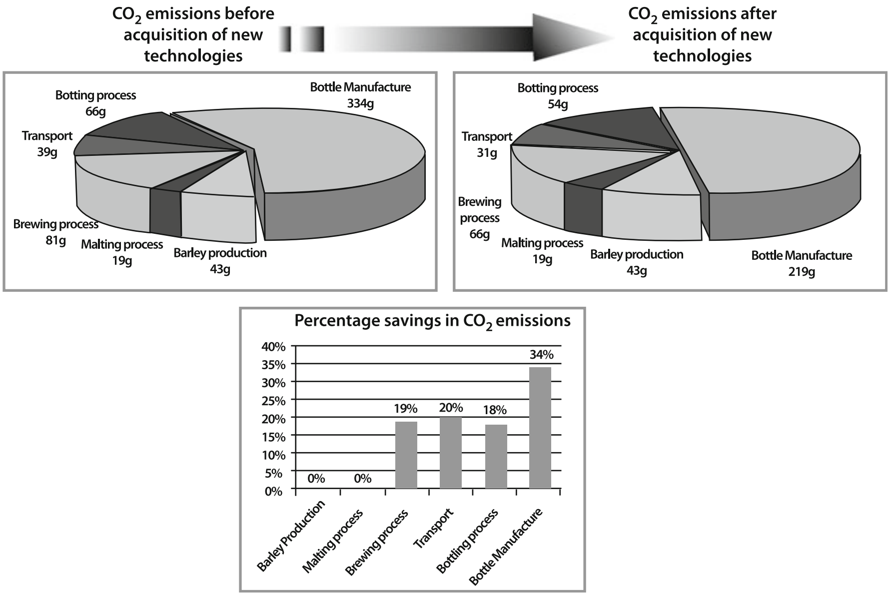

Fig. 10.4 East Green bottle of beer as an illustration of Adnams' greening process: CO_2 emissions pre-transition and post-transition (2006)

Ultra-efficient Brewing Equipment

One of the first heavy investments of the company occurred in 2006–2007 to replace the 100-year old brewing system with a brand new one which recycles 100% of the heat it uses to provide 90% of the energy for the next brew. The need to improve the brewing system principally emerged to provide Adnams with new capabilities intended to create a leaner production system, reducing wastage and related costs. The new system needs just 3 pints of water to produce a pint of beer. By contrast, the old machinery used 8 pints of water to make a pint of beer. The new brewing system is completely computerised which significantly reduces human activities and flows of material inside the brewery, thereby minimising potential areas of waste: for instance, it takes one person to run and monitor the brewing 'computerised' system. This brewstream, as it is called, hence represents a substantial shift forward in terms of eco-efficiency and cost reduction.

State-of-the-Art Distribution Depot

The second important move of Adnams in the quest for greener and leaner business activities consists of the distribution depot built in 2006 in the neighbouring village of Reydon. Adnams' investment marked the first UK commercial scale application of an innovative new building material now marketed as "Hemecrete" (a mixture of lime and hemp). According to Andy Wood, the decision to build this eco-efficient distribution depot was driven equally by business sense and environmental concern. The sunken buildings are almost invisible from the road – as they are built seven metres underground – and have grassed roofs which not only merge with the natural environment but use reed beds to catch and recycle rain water. The recycled water is then used in the plant, notably to water the grass roof, flush toilets and wash goods vehicles. The construction was executed with innovative material now enabling the firm to save 50% on electricity and gas and constituting substantial cost savings.

However, during the research visit, we did not notice any visible sign of active waste management. Also, Adnams still needs to deal with latent operational impediments principally caused by the use of different standards of palletisation of beers and wines among customers across Europe. This represents an inhibitor to the performance of the distribution centre – generating storage inconveniences – which currently proceeds to 8–12 deliveries per day. Moreover, the company is outsourcing bottling and the concomitant additional transports generate risks of dilution of responsibility in terms of total environmental impacts – generally considered as one of the latent downsides of industrial activities.[3]

Overall, however, the acquisitions of a new brewery system and innovative distribution depot gave Adnams the momentum to push the boundaries of eco-efficiency in addition to enhancing productivity and leaning business activities.

10.3.2 *Quantitative/Qualitative Business Benefits and the Move to Continuous Improvement*

The disposition of the company to put into effect green thinking and innovative technologies generates a number of quantitative and qualitative benefits which are, to some extent inadvertent, outcomes of a successful symbiosis of lean and green.

To begin with, the most visible, quantifiable business benefits are principally reflected by substantial cost savings from energy efficiency. While Adnams has significantly invested over the recent years with the purchases of a new brewing system and the distribution centre, the financial stability of the firm is not imperilled. In fact, the financial efforts consented are expected to pay off in the long term thanks to savings in energy and production costs – not mentioning quality improvement – that are now realised continuously. It is now apparent that engagement in green responsibility became part of the everyday processes in Adnams and, as such, does not require that much of additional resources to make this happen. The company is therefore doing increasingly better by being prevalently green. For instance, the operating profits recorded in 2009 at £922,000 are substantially

[3] The company has investigated the option of on site bottling and finds it to be more environmentally impacting than the current arrangement.

higher than the £142,000 achieved the previous year. The company holds a leading position within the sector as its main competitors are striving to regain competitive momentum by targeting the environmental standards of Adnams Brewery. The market conjuncture is also favourable with the notable revival of cask beers which is a strong heritage of the brewery.

In addition, the firm recently concluded a deal with supermarket giant Tesco for an exclusive 6 month distribution of the carbon neutral ‘East Green’ beer. The beer is now available bottled and on draught in 508 Tesco stores throughout the country. This move was initiated by Tesco who suggested the production of a carbon neutral beer to Adnams whose strong commitment to preserve the environment appears to find echoes among big retailers and beyond East Anglia’s borders. Meanwhile, the firm signed a 5 year agreement to supply Ipswich Town FC with beers at their Portman Road stadium replacing the 14 year old association with Greene King. With growing capabilities, productivity and better quality, the sustainable brewery is attracting and seizing new commercial opportunities.

On a more qualitative note, the firm also enjoys a strong brand image and growing reputation; in particular, the commitment to environmental and social responsibility helped the business to shape and reflect public opinion in a way that positively affects its “*license to operate*” (Andy Wood). The unsolicited initiative of Tesco is a meaningful illustration. The firm thus seeks to influence the influencers (lobbyists, legislators, opinion formers) to the company’s advantage via (in-house developed) socially responsible policies. Suppliers are also associated to the pursuit of green activities. However, while the Brewery sets high expectations on its suppliers to meet its environmental standards and is working not only up to but beyond regulations, thus outperforming competitors, the consumption side of the supply chain is still to be tracked. That is, wastage and/or CO_2 emissions generated by the consumption of Adnams beers are not yet estimated. The dotted arrow leading to consumption in Fig. 10.3 suggests that further efforts may be undertaken to optimise the firm’s impact on consumers. An objective may be to reduce CO_2 emissions on the consumption side of the supply chain with a view to strengthening the compatibility between EFF^2 and green and making truly ‘holistic’ improvements in the supply chain (Simons and Mason 2003). For example, plans to raise awareness through informational and/or persuasive[4] advertising methods (Siegel 2009) may be established. In a similar vein, Adnams is currently working in collaboration with external organisations, experts (including the University of East Anglia and its MBA programme) to further improve its lean and green performance. Through such partnerships, the company seeks to gain the competence to effectively measure all quantitative and qualitative benefits, thus continuously optimising its capacity to spot areas of improvements (Fig. 10.3: ‘continuous improvement’ box and Fig. 10.4). For example, it was through a

[4] Siegel (2009) distinguishes between persuasive ESR advertising and informational ESR advertising. Persuasive ESR advertising attempts to positively influence consumer tastes for products with ESR attributes. Informational ESR advertising merely provides information about the ESR characteristics or ESR managerial practices of the firm, and as such, is quite similar to ESR reporting.

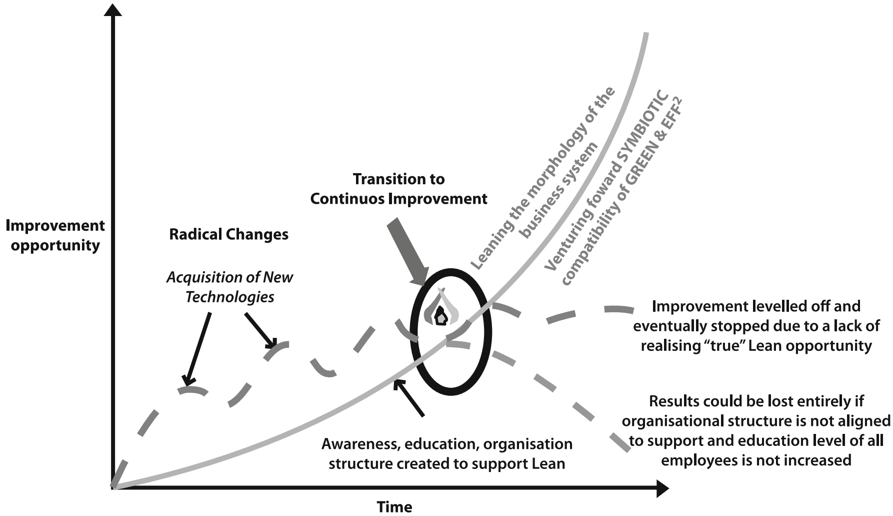

Fig. 10.5 Next stage in Adnams evolution: from radical changes to continuous improvement (Adapted from Hines et al. 2008, p. 7)

collaboration with Tesco[5] and the University of East Anglia over a thorough analysis of the whole supply chain – from the farming to the malt, to brewing, the bottling process and logistics, movement to the warehouse and delivery to the pub – that Adnams produced East Green via, The firm also worked with Cambridge University to investigate anaerobic digestion – i.e. the use of microorganisms to break down biodegradable material.

To sum up, the transition to effectively greener and leaner production practices has been radically boosted by the acquisition of innovative technologies and pro-ethical organisational values which took 15 years to put into place. This approach falls in line with Adnams' focus on sustainability. Yet, it does not fully satisfy the requirements for long-term environmental, social and business performance if it is not complemented or followed by a focus on continuous improvement. The positive results in terms of eco-efficiency and productivity emerged relatively fast. In fact, the heavy investments of Adnams in innovative technologies substantially accelerated the integration of environmental concerns into business operations but may not secure long-term, sustainable performance. In fact, the 'greening' strategy of Adnams cannot be strictly assimilated with the 'conventional' method of incremental, step-by-step improvements. It may be appropriate to envision a transition from radical improvement changes – with technological excellence as key driver – to continuous improvement by leaning the morphology of the business system – thereby tracking the consumer journey. Adnams would thus use a *more conventional* approach in its attempt to venture toward EFF^2. Figure 10.5 illustrates not only the need to use lean tools to improve performance but also the salience of

[5] Tesco was actually a partner in the development of the product as well.

encouraging behaviours focused on continuous improvement to provide sustainable long term improvement. Andy Wood sees the next stage in Adnams evolution to be a much more systemised way of measuring and communicating environmental issues both top-down and bottom-up.

10.4 Conclusion

The review of existing knowledge in the area of ESR leads to a number of propositions as to the integration of eco-friendly activities into businesses' strategic agendas – and therefore, provide a means for business to contribute towards a Green Growth agenda. We thus align with the work of Braungart and McDonough (2008) and echoe the propositions of Peter Drucker (1954, 1974). If businesses misjudge the salience of adopting ESR practices, they may loss sales and one of their most important assets, that is their reputation (Cruz 2009). We contend that the condition underpinning the moral tenability of ESR is often the achievement of a syncretic coherence with goals of growth and shareholder value creation. Ethical entrepreneurship and differentiation are viewed as potential pathways to syncretism with ESR integration contributing to reduce the production/manufacturing cost (Siegel 2009) and exploit marketing opportunities.

The compatibility between lean and green is framed as four stages: trade-off, ambidexterity, synergy and symbiosis. We further propose compliance of *lean/green* firms with a sustainable action plan based on the four system conditions of Robèrt (2002). Through this plan, we advocate the salience of five dynamic contingencies: consumption, business benefits, legislation, technology and corporate values. Brief guidelines drawing upon the dynamic contingencies for the simultaneous achievement of eco-efficiency and economic performance are suggested in Fig. 10.2.

The case of Adnams leads to examine a strategic pathway to the simultaneous achievement of green and economic performance. Figure 10.3 serves as an illustrative synthesis of the firm's strategy to address the five dynamic contingencies and *green* its activities. Most essentially, the framework highlights the prevalence of a top-down approach with visionary and scientific green proclivities generating substantial business benefits. That is, Adnams appears to place a strong emphasis on technological excellence and 'eco-friendly' organisational values instilled by top managers. These values are widely approved by shareholders and are claimed to incite employees' commitment. As a result, the firm became more productive while substantially reducing CO_2 emissions throughout the supply chains of its primary activities – as illustrated in Fig. 10.4 with the example of the East Green bottle of beer. The company is now seizing opportunities to grow its reputation, widen its commercial appeal and enter new markets – e.g. through relationships with Tesco, Ipswich Town FC. Competitors are now striving to catch up with Adnams which pro-environmental business vision and technological advancement can be considered as references in the brewing industry; therefore, making a wider contribution to Green Growth by pushing the boundaries and demanding that other then follow.

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Chapter 11
Participatory Research on Green Productivity of Silk and Cotton Woven Products in the Northeast Region of Thailand

Wanpen Wirojanagud and Chuleerat Promlao

Abstract This research was based on a participatory research approach aimed at improving the production methods of silk and cotton woven products to be environmentally friendly products. It was approximately designed to be in line with Green Growth and Sufficient Economy concepts. It was not a full technical research but it was an action research using the social process (participatory approach) to search for scientific findings that come up with enhancement of sustainable development. The action research was conducted at household level in the northeastern region of Thailand during 2008 and 2009 with a total number of 83 entrepreneurs participating. This kind of research requires willingness of entrepreneurs to participate and strong cooperation among line agencies, local authorities and the entrepreneurs. The technology transferred to the entrepreneurs includes cleaner technology and wastewater treatment process. Integration of the appropriate transferred technology with the local knowledge of production process resulted not only in more effective production processes, but also gave rise to green production towards sustainability.

Keywords Participatory research • Cleaner technology • Silk and cotton woven products • Sufficient economy • Green growth

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11.1 Introduction

The Sustainable Livelihoods Approach (SLA) is the social link to Green Growth (UNESCAP 2009c). SLA is a rights-based approach that is aware of the poor as a key stakeholder in the development process. SLA aims to support vulnerable communities with a pro-poor development program which links social and environmental sustainability. Participatory assessment is a key mechanism of SLA to achieve Green Growth through the process of identification of the main constraints, opportunities and concerns encountered by the poor and to include them into the policy, planning and implementation cycle. There are various projects implemented in Thailand following Green Growth and SLA concepts; this chapter is going to discuss one of them. In particular, the chapter is going to present a research project based on the participation of entrepreneurs in the area of green production of silk and cotton woven products at the household scale. The project was undertaken in the northeastern region of Thailand, during 2008 and 2009. It was conducted by The Research Center of Environmental and Hazardous Substance Management, Khon Kaen University with funding from Department of Environmental Quality Promotion (DEQP), Ministry of Natural Resources and Environment (MONRE). The main objective of this research was to enhance green productivity of silk and cotton woven household industry through participatory processes. The co-objective was to raise awareness of entrepreneurs and local authorities on environmental protection. Thirty-two entrepreneurs from 4 provinces in 2008 and 51 entrepreneurs from 7 provinces in 2009 were selected to participate in the project (Research Center of Environmental and Hazardous Substance Management 2008).

The chapter is structured as follows. First, we present the wider context in which the research takes place; outlining the principles of Green Growth and SLA and describing Green Growth and SLA policy and strategies in Thailand. Second, we describe the specific context of the research: silk and cotton production at the village level and its impact on community development. Finally, we describe the participatory research process applied and discuss its implementation and outcomes, analyzing achievements and challenges.

11.2 Green Growth and Sufficient Economy in Thailand

Over the past decades, rapid economic growth has encouraged development and investment worldwide, particularly in the Asian countries. Natural resources, which through the delivery of ecosystem services, provide noteworthy capital for the development of both economic and social sectors have been remarkably exploited while the generation of environmental pollution has substantially increased (UNESCAP 2009a). Under the conventional development concept of grow first – clean up later, ecosystems are subjected to continual exploitation. This inevitably leads to biodiversity loss, depletion of ecosystem services, desertification, loss of fertile land and atmospheric pollution, aquatic and marine pollution. Additionally, the environmental impact is felt globally as climate change, natural disasters and transboundary pollution. These impacts degrade our human well-being. It is mutually understood that such development with potentially adverse impacts cannot be further ignored, as its consequence is not only affecting the sustainability of our economies and ecosystems but also our quality of life. Consequently, all nations have been moving towards sustainable development – a holistic integration of economic, social and environmental dimensions. These dimensions are interrelated, implemented as the sustainable tools integrated with management tools. Economic tools (production, industry) embrace economic instruments (taxes, accounting, incentives), sustainable production and consumption, policy, funding support. Social tools (consumption) engage with information and networks, education, legislation, human resource development, training and awareness. Environmental tools (waste and resources) include standards and policies, and technologies. Management tools (governance and policy) take account of management system, corporate governance, life cycle assessment, cleaner production, cleaner consumption (Karazhanova 2008, 2009). All this tools are applied in Green Growth's policy-mix. Green Growth is defined as "*a process of economic growth (increase in GDP per capita) that maintains or reinforces ecosystems and their contribution to human health, well-being and quality of life*" (Ekins 2006). This is in contrast to the conventional processes of economic growth that tend to destroy and degrade ecosystems, particularly in the Asia and Pacific region. In other words, "*Green Growth is a policy focus that emphasizes environmentally sustainable economic progress to foster low-carbon, socially inclusive development*" (UNESCAP 2010; UNITAR 2011).

Regarding the policy context, Green Growth is a strategy for sustainable development. However, when consider as technical context, Green Growth is an eco-efficiency based strategy which advocates growth in GDP with protection of environmental quality and ecological integrity, as well as attaining the needs of all people with the minimum of possible environmental impacts. It is a strategy endeavouring to maximize economic output and minimize the ecological burdens (UNESCAP 2008a). Green Growth consists of four main pillars: eco-tax reform, sustainable consumption and production, green businesses, and sustainable infrastructure (UNESCAP 2008b).

The basic concept of eco-efficiency entails that goods are created using fewer resources and generating less waste and pollution. It implies a wise use of resources and a reduction in the ecological impacts of production. With the eco-efficiency approach, businesses are able to reduce their costs in a number of areas including production, distribution and overhead expenses. Such reduced cost can account for revenue for the companies. At the national level, the effective use of natural resources through eco-efficiency practice preserves resources to meet the needs of the human population. The promotion of eco-efficiency is enshrined in all four pillars of the Green Growth approach which will play a crucial role in the years ahead as countries in the region prepare to face increasing environmental challenges, particularly climate change. The main aspects of eco-efficiency are: reducing the material intensity of goods or services, reducing the energy intensity of goods or services, reducing dispersion of toxic substances, enhancing use of recycling, minimizing quantity of wastes and by-products, maximizing utilization of renewable resources and increasing the durability of products (UNESCAP 2008a).

Greening industry is a practical means for implementing the eco-efficiency strategy. Greening industry consists of integrating measures that prevent and minimize environmental degradation to water, air and soil, and problems related to waste, noise and eco-systems into the production of goods and services. Characteristically, it is scoped to the environmental management of the industrial areas focusing on pollution control and prevention, waste management and recycling, noise abatement, renewable energy, natural resources and energy efficiency. Green industry contributes to lowering environmental impacts of production and consumption processes through the application of environmentally friendly methods (UNESCAP 2009b).

In relation to the Green Growth approach, South Korea has been recognized worldwide for its successes so far. The green development framework of this country covers four elements, namely: (1) clean energy paradigm, (2) green technology as a new engine for growth, (3) improvement of the quality of life, and (4) green leadership (Woo 2009). Such Green Growth strategies are thus possible models for the direction of other countries.

In accordance with the endorsement of Green Growth by the fifth Ministerial Conference on Environment and Development in Asia and the Pacific (MCED-5) in 2005, Thailand is developing green growth policies and measures (Rujiwarangkul 2011). The Royal Thai Government has been amending an economic growth strategy to alleviate and adapt to climate change through low carbon green growth, relying on the recent advancements in resource- and energy-efficient policies, prominent steps towards sustainable infrastructure, consumption and production prototypes, as well as innovation and technological developments (UNESCAP News Services 2011).

Green Growth in Thailand was described by Mr. Rae Kwon Chung, Director, Environment and Development Division, ESCAP in the seminar on Green Growth Policy Tools Training Workshop for the Low Carbon Development in Thailand held at the UN Conference Centre, Bangkok, Thailand on 23–24 February 2011 thus: "*the green growth concept provides a rationale for a new development paradigm. It focuses on how to encourage and stimulate an economic system change by greening conventional economic systems that are based on the over-exploitation of natural resources and burning of cheap fossil fuels without paying the related ecological and social costs. Thailand and other countries in the Asia Pacific region need to focus more on the concept of "green growth" by balancing economic growth with ecological sustainability*" (UNESCAP News Services 2011).

In response to the Green Growth adoption, Thailand's 11th National Economic and Social Development Plan underlines the need for green growth pricing and legal tools to support change in energy production and consumption, and promotes new ways of life and consumption behaviour on the basis of national Sufficient Economy principles (UNESCAP News Services 2011). Thailand was pointed out as one of the most suitable countries in the region to embrace the motivation of the King's Sufficient Economy philosophy which is perceived to be very much in line with the principles of green growth. "*Sufficient Economy is a middle-path philosophy to achieve equitable and stable development, which is often referred to as sustainable development*", royally addressed by His Majesty King Bhumibol Adulyadej.

The Sufficient Economy concept has been promulgated by His Majesty King since the 1970s. But, curiously it has only been set in motion after the financial crisis in Thailand in 1997. The crisis created economic adversity at all levels, as people lost their jobs and confidence, which affected the country's socio-economic status negatively. Sufficient economy has been recognized as a mode leading the Thai economy towards more resilient, balanced and sustainable development as well as towards improved preparedness to any global changes (Asahayagchat 2008).

Codified by the National Economic and Social Development working group (unofficial translation of the Thai working definition approved by His Majesty and sent by His Majesty's Principal Private Secretary to the NESDB on November 29, 1999), Sufficient Economy is defined as "*a philosophy that stresses the middle path as an overriding principle for appropriate conduct by the populace at all levels. This applies to conduct starting from the level of the families, communities, as well as the level of nation in development and administration so as to modernize in line with the forces of globalization. "Sufficiency" means moderation, reasonableness, and the need of self-immunity for sufficient protection from impact arising from internal and external changes. To achieve this, an application of knowledge with due consideration and prudence is essential. In particular great care is needed in the utilization of theories and methodologies for planning and implementation in every step. At the same time, it is essential to strengthen the moral fiber of the nation, so that everyone, particularly public officials, academics, businessmen at all levels, adheres first and foremost to the principles of honesty and integrity. In addition, a way of life based on patience, perseverance, diligence, wisdom and prudence is indispensable to create balance and be able to cope appropriately with critical challenges arising from extensive and rapid socioeconomic, environmental, and cultural changes in the outside world*" – (Krongkaew 2003).

More importantly, in order to accomplish such philosophy, people have to become conscious of the major characteristics of Sufficient Economy which are (a) self-reliance, (b) wise use of resources, (c) moderation in terms of avoiding over production and consumption, and (d) cooperation/networking in economic activities and avoiding individualism. These characteristics can be elaborated on in terms of sufficiency as follows. *Sufficient in mind*: Be energetic, independent, conscience, compromise and not selfish. *Sufficient in society:* Be cooperative to make community strong, promote unity and most importantly have adequate knowledge. *Sufficient in nature resources and environment:* Know how to use and handle the resources, wisely and cautiously to improve efficiency. We must also manage resources sustainably so that are remained for our own and future generations' use. *Sufficient in technology:* Know how to use appropriate technology, particularly applying our local wisdom that is suitable to our environment. *Sufficient in economy:* Increase the income; decrease the expense and sustain life in a sufficient way. Live on our own individuality and position (UNEP RRCAP resources, ESCAP 2006).

In addition to the Green Growth approach, which emphasizes the interrelation of social and environmental perspectives, the Social Link to Green Growth

UNESCAP's Green Growth Programme has produced the Sustainable Livelihoods Approach (SLA). SLA is a rights-based approach that is aware of the poor as a key stakeholder in the development process. Participatory assessment is a key mechanism of SLA to achieve Green Growth through the process of identification of the main constraints, opportunities and concerns encountered by the poor and to include them into the policy, planning and implementation cycle. SLA supports vulnerable communities with the pro-poor development program which links social and environmental sustainability. "*The concept of sustainable livelihoods is used by some as a replacement term for sustainable employment and work in the formal and informal economies with reference to a person's capacity to maintain and enhance their capability and assets both now and in the future, while not undermining the natural resource base. Adopting this approach allows Green Growth to work towards win-win solutions: addressing the environment in ways which enhance opportunities for the poor to participate more fully in society and thus improving their quality of life*" (UNESCAP 2009c).

Obviously, we can see that Sufficient Economy shares many of the same ideals with Green Growth in seeking to achieve balance and sustainability. Both Green Growth and Sufficient Economy provide guidance towards decisions that will generate outcomes beneficial not only to the economic and social development of the country but also to the well-being of mankind. More prominently, the SLA program of UN ESCAP is directly linked to Sufficient Economy. Currently, there are a number of royal projects conducted in the rural areas based on the Sufficient Economy approach. There are also various projects implemented following the Green Growth concept including green building, green manufacturing, green procurement and green cities. The case study of Green Growth approach on green productivity of silk and cotton woven product is presented herein.

11.3 Green Productivity of Silk and Cotton Woven Products in Northeast Region Thailand

In developing countries, like Thailand, silk and cotton are important woven products for villages or communities, as they are based on local resources and created with local knowledge. In Thailand, silk and cotton products known as OTOP – One Tambon One Product show the uniqueness and characteristics of each community (Tambon in Thailand means Sub-district). OTOP production has supported local development and strengthened communities through job and income generation. Silk and cotton production at the village level is mainly a household industry. The production process, efficiency and product quality of this small scale industry are not always up to standard. In addition, there are problems of environmental pollution (Rakkhetpakdi 2008). This participatory action research was therefore undertaken in order to improve both the production efficiency and the quality of silk and cotton woven products; while at the same time ensuring environmental protection. The research demonstrated how to develop the

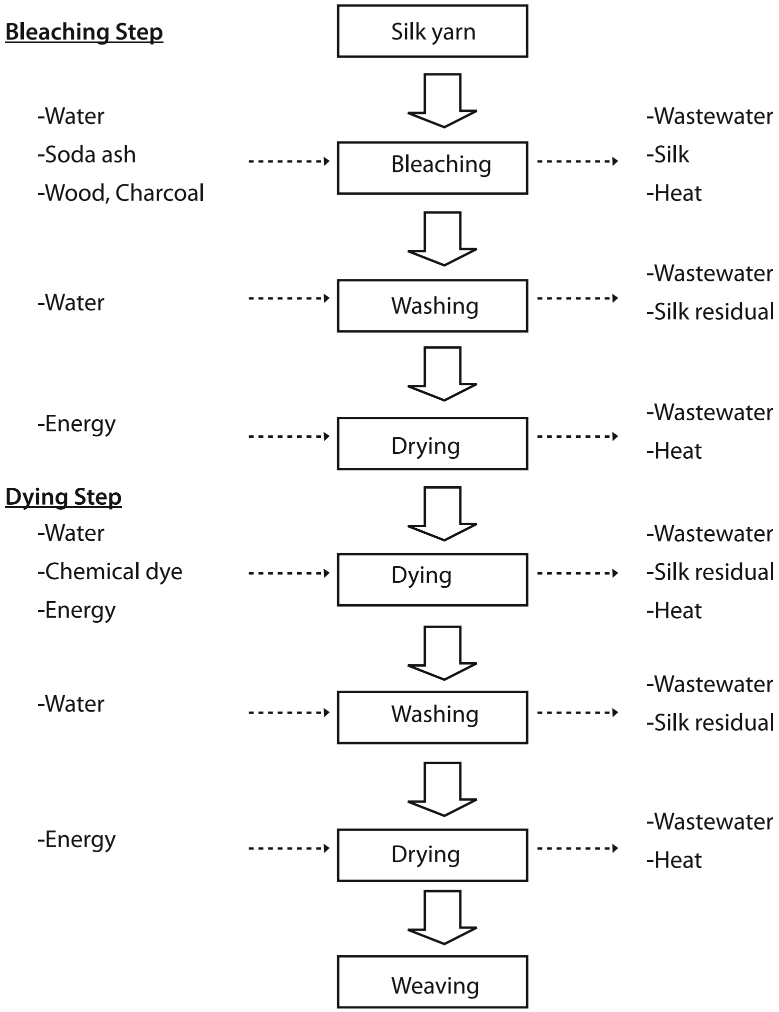

Fig. 11.1 Production process

networking capabilities of small scale industry for production of environmental friendly woven products (Green Productivity). In order to achieve sustainable production, the research integrated three core approaches: cleaner technology (CT), house keeping and wastewater treatment technology.

Prior to the main action of this project (participatory approach), the simple technology for silk and cotton woven production process is diagrammatically presented in Fig. 11.1 above and described as follows.

The raw material used in the silk production process is raw silk yarn (white colour) and the energy used is wood and charcoal. The production process is consisted of two main steps, bleaching and dying. The bleaching process is started by bleaching with water and soda ash, washing, drying. Then the bleached silk yarn goes through a dying process consisting of dying with chemical dye, washing, drying. Then, the dyed silk is goes for weaving. For a cotton woven product, the production process is same as for silk woven products, except the raw material is cotton. Since the production is at household scale, most entrepreneurs are housewives who spend their spare time producing such woven products. The production is performed by their own skill; they never measure water, chemicals or wood/charcoal uses. The major problem is overuse of water, energy and chemical dye. Some chemical dye contains toxic substances. In addition, waste water (which is not treated) is discharged directly onto the ground or to the stream nearby.

11.4 Research Process

This action research used a participatory approach following the Sustainable Livelihoods. The research process is presented in Fig. 11.2, below, indicating inputs, activities and outputs for each step in the process.

Step 1 involved the formation of the work team and preparation of the study plan by brainstorming. The work team consisted of academics from Khon Kaen University functioning as trainers, supervisors and mentors, and staff from relevant agencies (Provincial Industrial Office, Provincial of Natural Resource and Environmental Office, Regional Environmental Office, Industrial Promotion Office) who mainly worked as mentors. These mentors were also assigned as assessors or evaluators. Step 2 involved visiting entrepreneurs in various provinces in order to call for interested households/small scale silk and cotton industry. The selection of participating entrepreneurs was based on their willingness to attend training and manifested readiness to introduce environmentally friendly processes and technologies. Step 3 included training the assessors in order to ensure mutual understanding on the study's approach, evaluation criteria and process as well as give knowledge of CT, wastewater treatment technology and cleanliness in the work place. Step 4 involved training participating entrepreneurs in how to do the research (measurements, record keeping, etc) and in best practices for cleaner production and environmental protection (such as using non-hazardous dyes, minimizing water and energy use, and appropriate wastewater treatment) along with demonstrations of dying, washing, etc. Step 5 included initial assessments to find out conditions of the existing production process, work place and wastewater treatment systems. The entrepreneurs were taught how to record material, water and energy use, house keeping for cleanliness, and instructed in appropriate wastewater treatment systems (simple and economical basis). The entrepreneurs would then implement the practices that they could manage, particularly in order to meet the criteria for evaluation. During Step 6 the study team visited the participating entrepreneurs periodically as planned in order to assess any improvements after implementation of good practices and CT options. The progress and problems encountered were discussed. Step 7 included a meeting of all entrepreneurs and

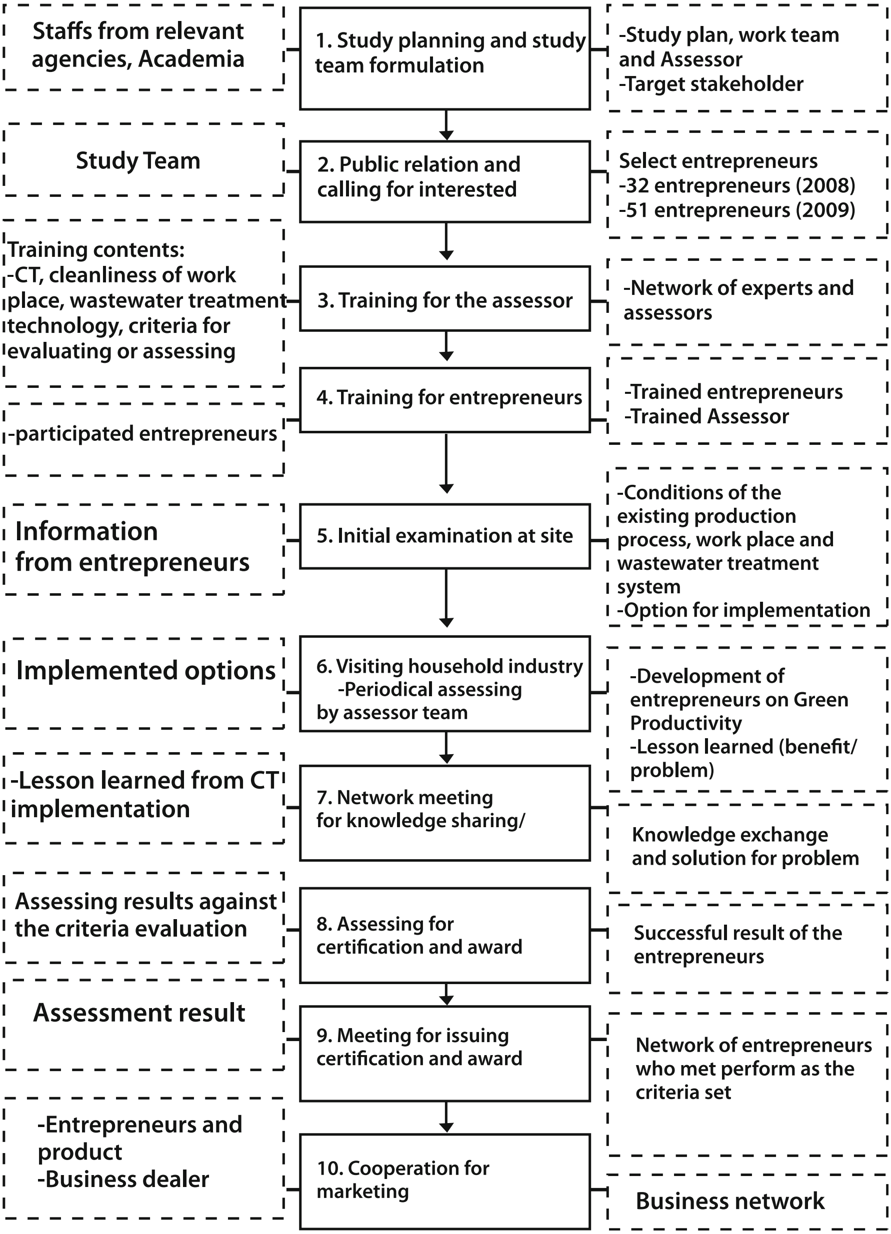

Fig. 11.2 Step by step study methodology

the research team to share and exchange experiences, particularly problems encountered in terms of participating in this kind of project. Knowledge management was undertaken through site visits to green productivity factories and group seminars. Step 8 was the final assessment and award of certificates. Certificates were awarded to the entrepreneurs who fulfilled the performance criteria. During the action research a network of entrepreneurs, the university and relevant agencies was formed. Steps 9 and 10 involved a meeting for award presentation and marketing. This would encourage the entrepreneurs for green productivity and at the same time provide opportunity for promoting their products and reaching higher production volume and better business opportunities.

In addition, performance evaluation criteria were established following the principle of environmentally friendly production defined as (a) Reduction or avoidance of hazardous raw materials, chemicals and dye; (b) Effective use of raw materials, water and energy in production process; (c) Utilization of renewable energy instead of non-renewable energy; (d) Recycling or reuse of raw materials, water and energy; and (e) Management of waste and pollution generated during production process. In order to accomplish such principle of criteria, the following items were listed for evaluation.

1. Quantity of cotton yarn, buying source, management of wastes generated.
2. Quantity of silk yarn, buying source, management of waste generated.
3. Quantity of yarn to be dyed, chemical dye, natural dye, mordant, water and fuel.
4. For natural dye, source of plant or dye material, means of getting such plant and dye material.
5. Not using chemical dyes that are in the prohibition list in accordance with the Directive Restriction on the Marketing and Use Certain Dangerous Substance and Preparations.
6. Quantity of water use per weight of product in all steps of production process.
7. Reuse and/or recycling of wash water and/or counter flow and not using water by overflow, as well as not washing the material in public stream.
8. Provision of personal protective equipment (PPEs), e.g. gloves, masks, boots, etc.
9. Provision of detection/measurement equipment and/or methods used for controlling production factors and maintaining such equipments in good condition ready for use.
10. Having measures that enhance the effective use of energy, such as using biomass from the residue, and having documented measures for energy saving.
11. Managing non-recycled and/or non-reused residues by the appropriate methods such as not burning materials, packaging or chemicals.
12. Having a plan of production improvements following cleaner technology or local wisdom with at least one plan with assignment of responsible person and designating time.
13. Good housekeeping including

    – Keeping and storing raw materials and products in appropriate places and using quality packaging.
    – Keeping and storing dye and chemicals in appropriate places with clear marking for identification
    – Marking purchasing dates, expiry dates, and following first-in and first-out principles.
    – Not finding leaking chemicals or expired chemicals

- Designated area for chemical and dye preparation, and dissolving dye completely
- Storing wastes, chemicals, and contaminated materials properly in appropriate places
- Not finding any water overflows or leaking
- Segregating wastes and reusing usable wastes
- Sweeping residues before washing (applying dry-cleaning practices)
- Screening cotton and other residues from wastewater prior to wastewater treatment system
- Keeping surrounding areas clean

14. For registered industries, the effluent from wastewater treatment system has to meet the effluent standard.

Each item in the performance evaluation criteria was given a score and the evaluation result was categorized as excellent, very good or good.

11.5 Research Assessment

Results and discussion are presented in accordance with the activity performed which might not follow the step by step process illustrated in Fig. 11.1. The collaboration of the academics and the responsible agencies as mentioned above (supervisor and mentor team) comprised the first group of stakeholders, called the work team. This work team was trained to have mutual understanding in CT approach, wastewater treatment, and setting criteria for selection. The main stakeholder group is the entrepreneurs at household level. The work team went to visit the villages, which have silk and cotton woven household industries. After the project had been explained, the interested entrepreneurs applied to participate. The selection was based on the designated criteria including willingness to attend training, readiness to improve production process and work place and implementation of wastewater treatment system. In 2008, there were 50 applicants from 4 provinces from which 32 entrepreneurs were selected to participate in the project. In 2009, the number of applicants increased to 79 from 7 provinces and 51 applicants were selected to participate in the project. The training of the entrepreneurs aimed to encourage them and make them capable of using green production methods to save cost and protect environment and human health. The training content included introduction to CT/house keeping and wastewater treatment, and green production processes. Good practice of silk and cotton dying process was demonstrated to them, particularly on dye utilization and washing of dyed silk/cotton yarn.

After training, the entrepreneurs started researching while doing their production under supervision of the work team. The entrepreneurs had been taught how to record all inputs (water, gas for fuel, firewood for fuel, silk, cotton, dye, other additives) and outputs/byproduct (silk/cotton, wastewater,) of the processes. This activity was performed to represent the existing situation (before application of the CT option). The study team visited them periodically in order to monitor their performance. The problems encountered included incomplete or no recording due to absolutely no prior experience with this type of activity. It has to be noted that some entrepreneurs are elderly people, who have little to no literacy. So their relatives had to help them doing the recording. During this step, we could identify the aspects that needed to be improved, e.g. water, energy, storage of materials. This was then the basis for CT options for implementation including water and energy saving, cleanliness of work place and storage of dye/raw silk and cotton, and wastewater treatment system.

The study team identified the following problems from the initial examination: (1) No or lack of wastewater management of dying process. This is due to the fact that most of the studied silk and cotton productions are household industries and they do not know how to treat wastewater. None of the existing Line Agencies is fully responsible for overseeing this scale or level of production. Some of the entrepreneurs have chemical treatment for dyed wastewater in the cement container. Alum and lime is first added to the dyed wastewater with stirring, it is left to settle and then the supernatant is passed through the charcoal filter for adsorption of dye, and discharge effluent to the environment. However, they do not know the exact amount of chemicals used. Most of them discharge wastewater directly to the environment. (2) Use of dye: the entrepreneurs who use chemical dye do not know the harmful effects of dye and they do not know how to use dye safely. (3) Water use: the entrepreneurs are not aware of water use since they get water from natural sources, surface or groundwater free of charge. (4) Cleanliness of work place was still a problem. Chemicals, materials and other stuff were placed and stored untidily, dying area located near or in the kitchen, etc.

Then the implementation of CT options, cleanliness of work place or house keeping and wastewater treatment were performed by the entrepreneurs. The assessment was accordingly conducted. Assessment of such implementation items including energy and water use reduction, chemical use reduction, waste management and improvements of the cleanliness of the work place were recorded as shown in Table 11.1.

It should be noted that, in general, more than 60% had improved their production process based on evaluation criteria (CT/house keeping/wastewater treatment system) approach, except the item on cleanliness of work place presented as 42% in 2008 and no using dye and chemical in the prohibiting list still presented as 43% in 2009. Comparing the performance of 2008 and 2009, in general the performance of 2009 (67–80%) was better than the performance of 2008 (42–74%), except the items of no using of dye and chemicals in the prohibiting list and appropriate wastewater treatment system where the figures were 65% (2008)/43% (2009) and 71% (2008)/61%(2009), respectively. Besides, it should be noted that the criteria for 2009 was more stringent than the 2008 criteria. That was one of the reasons behind percentage drops for such items. Among the items implemented, the highest percentage of entrepreneurs introduced personnel protection equipments (PPE): 74% in 2008 and 80% in 2009. The high rate of PPE introduction is due to a

Table 11.1 Assessment of energy and water use after implementation of cleaner technology

Criteria	2008 (32 entrepreneurs) (%)	2009 (51 entrepreneurs) (%)
1. Energy use	61	67
Reuse of fuel		
Improvement of large size energy		
Saving stove to be good condition		
Using energy saving stove		
Reuse of firewood residue from dye cooking for fuel		
Keeping firewood and charcoal under the shed or in the firewood house		
2. Water use	61	69
Reuse of water from dying process		
Bleaching and dying for high amount at a time		
Not use excess chemical dye		
Not let water overflow		
3. Do not use dye and chemicals in the prohibiting list	65	43
4. Having personnel protection equipment (PPE)	74	80
5. Having a right management of unusable materials	65	75
6. Appropriate wastewater management	71	61
7. Cleanliness of work place	42	80

heightened awareness among the entrepreneurs of the dangerous of chemicals after they get training. Beside, these PPE are relatively affordable. Surprisingly, cleanliness of work place could be made as high as 80% in 2009 compared to 2008 was only 42%. The large increase for this item is because of more monitoring by the work team in 2009 than 2008. The cleanliness or house keeping is easy to implement but required a very high intention and responsibility. In terms of implementation of the options, not all of the entrepreneurs were successful – in particular with respect to wastewater treatment system. It is very hard to teach and convince household entrepreneurs to pay and invest in wastewater treatment system even for low cost solutions. In one locality, the Sub-district Organization Authority had provided the budget for installation of wastewater treatment system for a group of household industry. They could cooperate and work as a group by arranging place for dying, and discharge wastewater to the central wastewater treatment system. This implies that cooperation with authorities and internally among the entrepreneurs is one of the important factors in ensuring the project's success.

The evaluation of performance of participating entrepreneurs in the 2008 study result included 1 excellent, 1 very well and 6 good, indicating that only 8 out of 32 entrepreneurs (or 25%) met the criteria of environmentally friendly production In 2009 there were 6 excellent, 6 very good and 3 good, representing 15 out of 51 entrepreneurs (or 30%) that met the criteria. The successful entrepreneurs received awards in the form of the gold, silver and bronze medals, given by DEQP. The results indicate the increasing number of interested entrepreneurs and their intention to join this action research as they could see the benefits to the production process and environmental encouragement and awareness.

However, there was still a high percentage of the entrepreneurs who did not get awards: 75% for 2008 and 30% for 2009. There were many reasons for these unsuccessful entrepreneurs including using prohibited dyes and chemicals, lack or no implementation of wastewater treatment system as they did not have budget for the wastewater treatment unit. To make this project successful, not only willingness from the entrepreneurs but also the budget for wastewater treatment has to be worked out.

11.6 Conclusion

This kind of project is applied research being implemented in the community. It is not fully technical research. This research would like to present the participatory research involving all the stakeholders under the concepts of mutual interest, mutual respect and mutual responsibility. The key stakeholders are the academics, responsible agencies at central, provincial and local level, and the entrepreneurs. The knowledge transfer from academics on related subjects including cleaner technology or green productivity, cleanliness practice for work place, wastewater treatment system, and knowledge exchange among the entrepreneurs forms the knowledge base that ensures that the entrepreneurs and the responsible agencies are able to the implement the right approach. The Local Authority Organization should provide strong cooperation and support to development of environmental friendly productions and products. Not only high but also green productivity are fundamental to sustainability.

Production of silk and cotton woven products happens at household level with the application of local wisdom. However, most of the entrepreneurs have never thought about saving of natural resources since they can get such resources (wood from forest, water from surface water or ground water) free of charge. With the technology transfer of cleaner technology as well as wastewater treatment, it would enable them to practice effective resource use, waste minimization and appropriate treatment of waste. In addition, the entrepreneurs can create networking for knowledge exchange in green productivity and other relevant subjects. This project illustrates Green Growth in line with the Sufficient Economy approach, particularly the participation of the entrepreneurs for production of environmentally friendly products, moving toward a sustainable economy and livelihood.

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Chapter 12
Attitudes Towards Energy Efficiency and Renewable Energy in European Small and Medium-Sized Enterprises

Juha T. Kortelainen, Mari Ratinen, and Lassi Linnanen

Abstract The European Union has set goals to tackle climate change by increasing energy efficiency and renewable energy use. A survey in eight regional groups of small and medium-sized enterprises in different member states was conducted and analysed to show how these goals are achieved by the end users. The attitude towards energy efficiency improvements seems to be more positive than that towards increasing renewable energy use. Based on the survey, the enterprise size measured by the average number of staff members and annual turnover correlates with the attitude towards renewable energy and the staff size with the attitude to energy efficiency. Enterprises in member states that joined the EU in 2004 or later view energy efficiency more positively than those in older member states. The number of investment appraisal methods applied correlates with attitudes towards both energy efficiency and renewable energy. The ability to allocate energy costs to projects or products is linked with the experienced significance of energy and the attitude to renewable energy. Clearly, one of the most important factors in attitudes towards renewable energy and energy efficiency is the nationality of the answerer. National and regional energy policies, markets and culture seem to have more influence on attitudes than the common goals of the European Union. In future, SMEs and their distinctive qualities need to be addressed when initiating future energy-related programmes with them.

Keywords Energy efficiency • Energy attitudes • European Union • Renewable energy • SMEs

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12.1 Introduction

In its effort to pursue green growth and meet the challenge of climate change, the European Union has established goals and policies. However, at the level of a single enterprise these goals could seem irrelevant and unimportant. This chapter discusses the attitudes towards improving energy efficiency and increasing renewable energy use in eight European regional groups of small and medium-sized industrial enterprises. For this purpose, a survey measuring these attitudes was developed. The data was analysed using statistical means to find the determining factors for the attitudes within the regional groups. These analyses were carried out using SAS Enterprise Guide software and appropriate tests were chosen in accordance with the variable type, number of classes, and type of distribution. Finally, some implications for policy-making and future energy programmes are also discussed.

12.2 Small and Medium-Sized Enterprises and Environmental Innovations

The majority of businesses in Europe belong to small and medium-sized enterprises (SMEs) (Hillary 2004; Zorpas 2010). Even though according to Zorpas (2010) in SMEs environmental management systems are becoming more common and provide numerous internal and external advantages, SMEs are still often thought as being slow in adopting environmental innovations into their practices. According to del Brío and Junquera (2003), SMEs tend to take compliance to legislation and rules as their environmental strategy instead of acting as forerunners. Reasons for this can be found in limited financial resources, peculiar characteristics of organizational structure, management style, human resources, environmental management status, manufacturing activity, technological approach, restricted innovative capacity, and limited external cooperation. Also, it should be remembered that the impact on the environment is not necessarily dependent on the size rather than nature of the operations. The environmental impact of a single enterprise can be small, but because there are a vast number of them, they have a substantial significance (Gadenne et al. 2009).

In SMEs, the role of the entrepreneur as a decision-maker is more visible than in larger corporations. An entrepreneur's innovativeness has underpinnings in social human capital but also in psychological aspects. Personal traits have an effect on their behavioural, normative and control beliefs, which in turn affect the intention to perform the behaviour; for example, to adopt a green innovation (Marcati et al. 2008). An enterprise is not situated in a vacuum: it has several stakeholders which form a network around it. A Dutch case study in aluminium regeneration shows that the social network of suppliers, customers, governmental organizations and others also plays a role in the diffusion of cleaner technology (Verheul 1999). Thus, the spreading of an environmental innovation in SMEs is attributed to several characteristics. The entrepreneur or someone in the organization makes the decision according to his own insights and evaluations. Personal decisions have a greater role in SMEs than in larger organizations. Cultural factors also need to be addressed: the industry or sector can act as an inhibitor or promoter for an innovation. National and regional culture also need to be taken into account.

In SMEs, environmental practices and intentions do not necessarily go hand in hand. Gadenne et al. (2009) list three reasons for adopting environmental management practices in SMEs: economic benefits, adopting practices for compliance, and personal awareness. For some, environmental conservation is ethically the right thing to do. However, they come to a conclusion that even if some entrepreneurs in SMEs have high personal standards in the environmental performance, this is not necessarily transmitted to their business operations. Instead, if environmental practices have a cost benefit or are expected to be of advantage to the enterprise in the future, the measures are implemented. Whereas Gadenne et al. (2009) did empirical research in Queensland, Australia, similar findings were made also by Cassels and Lewis (2011) in New Zealand. Their survey found that 41.9% of the enterprises had not set measurable targets for energy usage, which is far more than e.g. some common waste management practices. The majority of the manufacturing SMEs did not consider their environmental impact. However, only 16% of the owner-managers gave no consideration to it at all. As mentioned also in del Brío and Junquera (2003), most of the entrepreneurs would wait for legislation to implement environmental measures. Based on the two individual researches, it can be stated that the positive environmental attitude of the entrepreneur does not necessarily result in environmental actions in the SME.

As environmental management schemes are implemented in an increasing numbers to SMEs, energy management can use similar logic (for an example, see Kannan and Boie 2003). A Dutch survey among the most energy intensive industries in the country gives an insight into the decision-making in the firms. According to de Groot et al. (2001), the single most important reason for investing in energy efficiency is the potential to achieve cost savings. However, if there are more financially appealing investment alternatives, these are chosen over energy efficiency. The study also displayed evidence from industry- and firm-specific factors in investment behaviour. An Australian study showed that although environmental concerns are listed as important in terms of energy investments, the firms are conservative. The survey was done for an energy efficiency programme which included audits. In an average audit, six energy efficiency improvements were listed. The suggestions were carried out to a very limited degree, which also supports the ‘gap’ between attitudes and action (Harris et al. 2000). In a Swedish case, a better rate of implementation was achieved, but barriers for investments included lack of access to capital or relevant information and energy efficiency being non-priority (Thollander et al. 2007).

Based on the literature review, SMEs are not an ideal ground for promoting energy efficiency and renewable energy use. Because the decision-making in SMEs is commonly done at the level of an individual, and perhaps without an implemented guideline, the psychological qualities of an entrepreneur have also a role to play in energy decisions. Attitudes can have some impact, but, as was suggested by Gadenne et al. (2009) and Cassels and Lewis (2011), they do not always turn into action. Considerable risk aversion seems to lurk around energy and environmental decisions, and energy is considered to be just a cost, and not necessarily a very significant one. Externalities of energy use are not considered either. Even if an entrepreneur were to have a will to improve the situation, some more urgent matters tend to pass by energy and environmental issues (Cassels and Lewis 2011). Around the world, there are examples of energy programmes reaching for individual consumers. Behavioural change (see Gynther et al. 2012) in SME manager-owners would also need to provide a financial advantage, which can be hard to prove. If there are also possibilities for downturns or risk for sunken costs for the energy investment, a risk averse entrepreneur leaves things as they are. This leaves the SMEs in the position depicted by del Brío and Junquera (2003): SMEs are laggards in energy management due to some of their typical characteristics, generally taking lack of financial, knowledge, or human resources and concentration in production-related issues. Furthermore, if small activity in innovation and use of external co-operation is added to this, energy management does not have an optimal breeding ground.

12.3 Energy Goals of the European Union

The EU has several targets to increase renewable energy production and energy efficiency. The aim of the White Paper in 1997 (COM (97) 599) was to increase renewable electricity production in EU member states from the current 6% to 12% by 2010, but there were no country specific targets. In 2001, RES-E (2001/77/EC) specified that the overall target for the EU was to increase electricity generation from renewable sources by 22% by 2010, and this target was complemented with country specific targets. The EU's emission trading scheme to stimulate renewable energy production was implemented in 2005. The Action Plan for Energy Efficiency: Realising the Potential (COM (2006)545), again with country specific targets, was published in 2006. Finally, new targets for renewable electricity production were introduced in 2009. The overall target for the EU was to increase renewable electricity production by 20% by 2020, with additional country specific targets (2009/28/EC).

The member states have their national energy policies that specify the actions and technologies perceived appropriate. Consequently, there are considerable differences in the scope and manner in which renewable energy generation and energy conservation have been encouraged in the member states (EC 2010). Electricity generation from renewable sources is supported through feed-in-tariffs and/or through Green electricity certificates in all member states except Finland (tax subsidies), Latvia (solely quota obligation), and in Malta (tax subsidies) (Foquet 2007).

12.4 Energy Attitudes in Eight Groups of European Small and Medium-Sized Enterprises

In order to collect data for analysing the eight different groups of enterprises, a survey was carried out during January and February 2010. The questions dealt with energy efficiency, renewable energy, and costing – without forgetting background information about the enterprises. Most of the data was gathered by telephone or in personal interviews, and in some cases, with web-based survey engines. Altogether, there were 187 answers from eight EU countries: Bulgaria, Estonia, Finland, Hungary, Ireland, Italy, Slovenia, and the United Kingdom. Of the participating countries Estonia, Hungary, and Slovenia joined the EU in 2004 and Bulgaria in 2007. In this paper, these four are considered as new member states and the remaining four as old ones. Enterprises from Finland, Italy, and Slovenia represented the engineering industry and Estonian ones sawmilling. The remaining four countries represented more or less mixed-industry businesses operating in the same geographical region. Based on the literature, single SMEs usually are not forerunners in energy management, energy efficiency or renewable energy use. The reason for this survey is in a European project creating a common energy agenda within regional groups of enterprises instead of merely applying governmental regulations of European, national or regional level. In order to address the right issues (level of knowledge, attitudes, resources) the survey was chosen as a way to form a picture from the needs of the enterprises. (See Acknowledgments for more details on the project) (Table 12.1).

The enterprises were guided to obtain answers from the person mainly responsible for energy-related decisions. Figures 12.1 and 12.2 below shows the number of respondents per member state and the respondents' position in the enterprises.

It should be remembered that there is not enough material to make generalizations and that the enterprises were chosen to match the cluster profile. Thus the results could be too biased if taken out of their context. In the survey, relevant questions for this paper were the following:

1. Average number of staff members
2. Annual turnover
3. On a scale of 1 to 10, how important do you consider energy for your business? (1 not important; 10 very important)
4. What is your company's position in relation to energy efficiency improvements?

   Evaluate the following statements: (scale of 1. . .7, where 1 disagree; 7 agree)

   (a) Every individual and organization must do their share in improving energy efficiency.
   (b) Our organization cannot do much to improve energy efficiency.
   (c) Energy efficiency has several advantages for our business.
   (d) It is reasonable to approach energy issues systematically.

5. Is there an energy management system in your company?

Table 12.1 Average enterprise size in the sample

	Staff	Turnover
ALL	49	6,149,304
Bulgaria	43	738,021
Estonia	53	2,296,250
Finland	42	11,339,091
Hungary	48	5,111,878
Ireland	144	13,100,000
Italy	38	9,060,833
Slovenia	131	6,660,244
UK	45	3,781,250

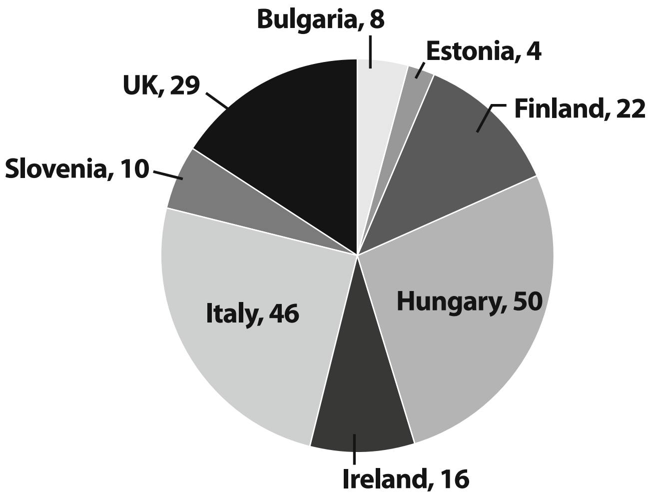

Fig. 12.1 Number of respondents from each member state

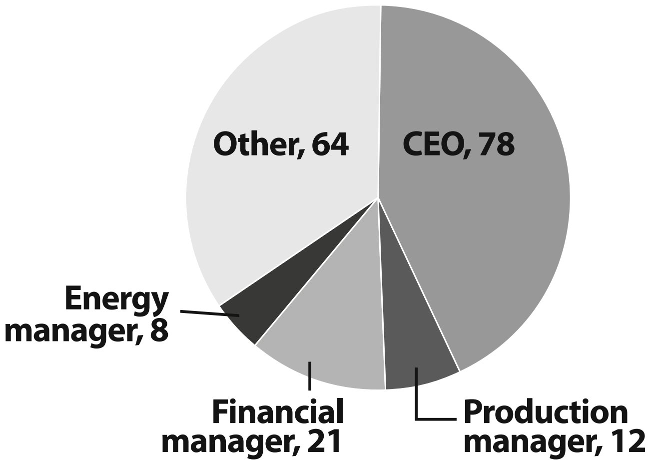

Fig. 12.2 Respondents' position

6. What is your company's position in relation to increasing the use of renewable energy?

   Evaluate the following statements: (scale of 1...7)

   (a) Every individual and organization should increase the share of renewable energy in their energy use.
   (b) Renewable energy is not relevant for our operations.
   (c) Renewable energy has several advantages for our business.
   (d) Renewable energy is appealing even if it would cost more than non-renewable.
   (e) Renewable sources (e.g. solar/wind/hydro/biomass) may be available locally.

7. Are energy costs in your organization treated as overheads or are they allocated?

   Directly to projects or products, as overheads or do not know?

Additional variables for attitudes towards energy efficiency and renewable energy were also calculated. For energy efficiency: 4a − 4b + 4c + 4d and for renewable energy: 6a − 6b + 6c + 6d + 6e. The experienced significance of energy, summed energy efficiency attitudes, and summed renewable energy attitudes are tested against different factors. Questions were chosen to measure respondents' attitudes with several indirect questions instead of one to reduce the possibility of bias in the answers. The use of cost allocation was included to measure the costing knowledge, especially the use of activity-based costing, an idea which Johnson and Kaplan introduced in their book *Relevance Lost – The Rise and Fall of Management Accounting* in 1987. In activity based costing, costs are allocated to projects, products or customers according to their use of resources. Implementing activity-based costing could also lead to better energy management if the sources for costs are analysed with adequate accuracy.

In order to choose an appropriate statistical test, it is necessary to know if the variables are normally distributed. This can be done by using the Kolmogorov-Smirnov analysis. With a 95% certainty level, none were normally distributed. For each test, the minimal value for abandoning H_0 is 0.05, and the test values from the analyses are shown respectively.

12.4.1 Results for Energy Attitudes

Three variables (experienced significance of energy to business, attitude towards increasing renewable energy use, and attitude towards improving energy efficiency) are discussed in this chapter. Their distributions are shown in Figs. 12.3, 12.4, and 12.5 below. It can be seen that energy is considered very significant in European small and medium-sized enterprises.

As for energy efficiency improvements and increasing renewable energy use, distributions are quite different, although it should be noticed that the scale is also different. The average for energy efficiency is 14.134 (max. 20), whereas for

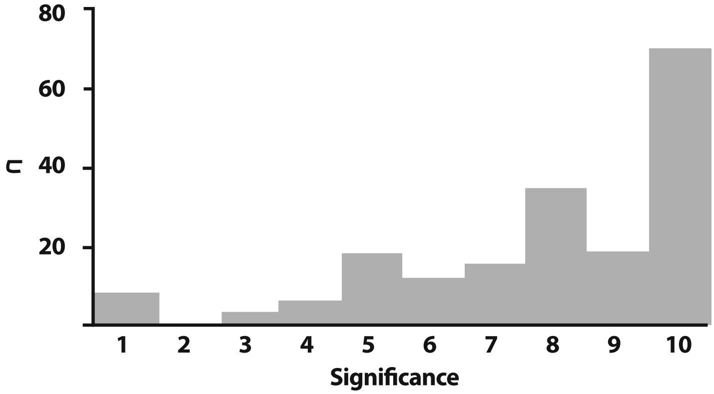

Fig. 12.3 Significance of energy vs. number of respondents

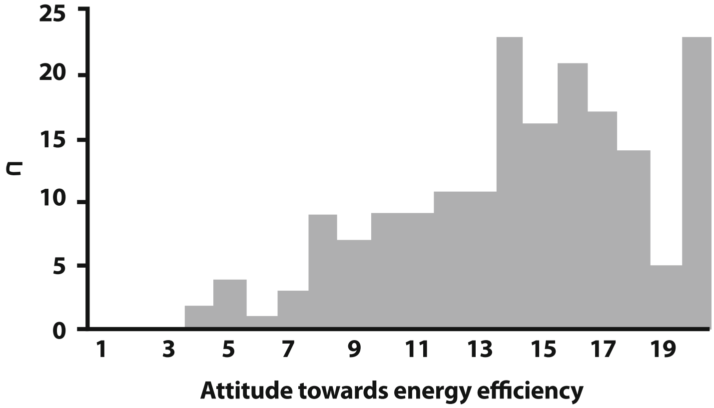

Fig. 12.4 Attitude towards energy efficiency vs. number of respondents

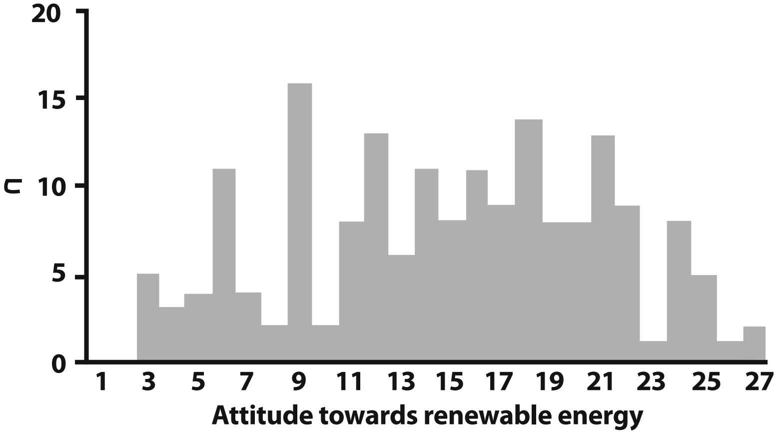

Fig. 12.5 Attitude towards renewable energy vs. number of respondents

Table 12.2 Correlation of experienced energy significance with business size

	Correlation factor	P-value	Result
Turnover	−0.00040	0.9963	No
Staff	0.12960	0.0838	No

Table 12.3 Correlation of attitude towards energy efficiency with business size

	Correlation factor	P-value	Result
Turnover	0.11085	0.2006	No
Staff	0.16676	0.0257	Yes

Table 12.4 Correlation of attitude towards renewable energy with business size

	Correlation factor	P-value	Result
Turnover	0.17858	0.0390	Yes
Staff	0.21376	0.0042	Yes

renewable energy it is 14.6 (max. 27). The standard deviations are 3.988 and 6.303, respectively. Judging by these numbers, it can be stated that the attitude towards increasing energy efficiency is more positive and there is not as much deviation in the answers as in the answers related to renewable energy.

12.4.2 Effects of Enterprise Size

It is a usual assumption that larger organizations tend to take a more systematical approach to energy issues than small ones (Kannan and Boie 2003). Regression analysis was applied to see if there is a correlation between enterprise size indicators and the experienced significance of energy or summed attitude variables. For the size, the annual turnover and the average number of staff members were used for testing correlation.

The hypotheses are:

H_0: There is no correlation between the enterprise size and energy attitudes.
H_1: There is a correlation between the enterprise size and energy attitudes.

The variables are not expected to be normal distributed, and therefore, the Spearman correlation factor is used. The results are presented in Tables 12.2, 12.3, and 12.4.

At 95% certainty levels ($p = 0.05$), H_0 applies in neither the size measurement for renewable energy correlation, nor in the staff size for energy efficiency. Thus, it can be stated that, on the tested material, attitudes towards renewable energy correlate with both measures of enterprise size, attitudes towards energy efficiency correlate with number of staff members, and that the experienced significance of energy does not correlate with the enterprise size. This finding also supports the literature and earlier research done in the area.

Table 12.5 Country dependence of measured factors

	X^2	$p > X^2$	Dependent
Significance	12.0906	0.0976	No
Efficiency	19.7151	0.0062	Yes
Renewables	56.7583	<.0001	Yes

Table 12.6 Differences between old and new EU countries

	$p > \lvert Z \rvert$	Different
Significance	0.3944	No
Efficiency	0.0202	Yes
Renewables	0.1149	No

12.4.3 Effects of Nation

Because the same questionnaire was introduced in eight countries at the same time, it could be tested whether the answers were dependent on the member state. In some countries, only a few answers were received, and consequently, those results are not statistically valid. Using the Kruskal-Wallis test, the similarity of distribution for the experienced significance of energy and the attitude towards energy efficiency and renewable energy in the countries could be tested. The hypotheses are:

H_0: The mean value is the same in all countries.
H_1: The mean value differs between countries (Table 12.5).

The attitude towards energy efficiency and renewable energy differs from one country to another. Energy efficiency improvements were best received in Ireland and Slovenia, and the increase of renewable energy in Bulgaria and Italy. In the latter category, the two countries are the most ideal for using photovoltaic or some other form of solar energy. Respondents from the United Kingdom had clearly the least positive stand on both of the issues. Hungarian enterprises were the second least positive regarding renewable energy and Italians regarding energy efficiency improvement after Estonia, from which only four answers were received.

New members joined the EU in 2004 and 2007. The difference between the old and recently joined members was also tested in terms of the three variables. The Mann-Whitney test was used to find the differences. The hypotheses are:

H_0: The mean value is the same in all countries.
H_1: The mean value differs between the old and new EU countries (Table 12.6).

From these tests, it can be concluded that the outlook on energy efficiency is more open in the new EU countries (mean score 102.6) than in the old ones (mean score 84.0). However, it should be kept in mind that the attitude to energy efficiency also depends on the country itself and possibly on the branch of industry, not only on its status as a new EU member state or formerly planned economy.

Table 12.7 Allocation/overheads treatment of energy costs to measured factors

	X^2	$p > X^2$	Dependent
Significance	6.646	0.0360	Yes
Efficiency	4.7567	0.0927	No
Renewables	9.4005	0.0091	Yes

Table 12.8 Correlation between the number of investment appraisal methods and measured factors

	Correlation factor	P-value	Result
Significance	0.15145	0.0741	No
Efficiency	0.18386	0.0297	Yes
Renewables	0.23053	0.0061	Yes

12.4.4 Effects of Costing Knowledge

Some data concerning the costing aspects of energy were also gathered. The basic assumption is that if an enterprise is able to allocate energy costs directly to a project or product instead of just using overheads, it also has an interest in energy issues. A Kruskal-Wallis test was carried out to see if costing and energy attitudes are linked.

H_0: The mean value is the same whether an enterprise allocates costs or uses overheads or is not able to answer.
H_1: The mean value differs between costing types (Table 12.7).

There is a statistically valid linkage between experiencing energy as significant and allocating energy costs instead of using overheads. This applies to the attitude towards renewable energy as well. It is not clear which affects which: whether costing affects attitudes or attitudes affect costing.

The enterprises were also asked about their use of investment appraisal methods. The number of methods listed and their correlation with attitudes was then tested. The assumption is that companies with extensive knowledge on investment methods would pay more attention to energy efficiency in order to minimize costs.

H_0: There is no correlation between the investment appraisal method use and energy attitudes.
H_1: There is a correlation between the investment appraisal method use and energy attitudes (Table 12.8).

Once again, the significance of energy is not correlated with the tested factors. However, for energy efficiency and renewable energy, the number of investment appraisal methods is visible. When comparing individual questions forming the summed variable, knowledge of investment appraisal methods correlates in most cases, and in six out of nine questions it correlates more than staff or turnover. This could be because enterprises aware of investment appraisal methods are also aware of possibilities in energy efficiency and renewable energy.

Table 12.9 Occurrence of energy management in sampled SMEs, frequencies on the left and proportions on the right

	No	Yes	Does not know	No	Yes	Does not know
ALL	144	37	4	0.78	0.20	0.02
Bulgaria	6	2	0	0.75	0.25	0.00
Estonia	4	0	0	1.00	0.00	0.00
Finland	20	2	0	0.91	0.09	0.00
Hungary	44	6	0	0.88	0.12	0.00
Ireland	6	10	0	0.38	0.63	0.00
Italy	34	9	3	0.74	0.20	0.07
Slovenia	8	2	0	0.80	0.20	0.00
UK	22	6	1	0.76	0.21	0.03

12.4.5 Commonness of Energy Management

It is a common belief that energy management is more usual in large companies. According to the sample in this study, this seems to be true. Energy management is applied only in 20% of the enterprises, and it is more common in local subsidiaries of national or multinational corporations. In other words, energy is merely used, and the advantages for it to be managed in any way are seen difficult to attain or unimportant. Compared to other environmental impacts, the use of energy is a very abstract one. It is also in the nature of energy that from time to time the ownership of energy-utilizing processes is very hard to determine. This survey does not disprove the statement that SMEs are not very aware of the possibilities of energy management (Table 12.9).

12.5 Summary of Results

Based on the analyses, it was found that enterprises view energy as generally important to their business, and no defining factors were found for experiencing energy less or more important. Costing knowledge seems to be linked with the importance of energy, but from this data it cannot be determined clearly which affects which.

Several linkages to the increase of renewable energy were found. Larger enterprises have a more positive attitude to renewable energy, when measured in annual turnover and the number of staff members. The answers seem to depend also on the country, but no difference between the old and new EU member states was observed. The ability to allocate energy costs was found to be connected with a positive attitude to increasing the use of renewable energy, as well as the usage of several investment appraisal methods.

The attitude towards energy efficiency improvements was found to be interdependent with the number of staff members, using several investment appraisal methods and the country. A difference was also found between the old and new

EU countries: in this data, the new member states have a more positive attitude towards improving energy efficiency than the old ones. This could result of a need to renew and modernize some of the technology.

It seems that the attitude to renewable energy is linked more closely to different factors, but the idea of improving energy efficiency is not linked to other aspects. As for EU policy, energy efficiency appears to receive wider and more consistent acceptance in the tested small and medium-sized enterprises than renewable energy. In addition, national policies in the examined areas should also be taken into closer review before trying to define differences between regions.

Although the attitude towards energy issues is commonly positive or at least neutral, it is impossible to say how much of these attitudes would turn out to lead in investments to energy efficiency or renewable energy. Perhaps it can be stated that most of the operations within the enterprises would not happen if there, for some reasons, were no energy available. The availability of energy is a typical situation. During interrupted distribution the significance and dependence on energy in the modern society truly reveals itself.

12.6 Discussion

Common European Union goals to drive green growth are hardly reflected at the level of a single enterprise. There are, of course, differences that can result from national policies. In short, this study shows that a great deal of attention should also be paid to the grass roots level and bottom up approach, not only to the top down approach. By improving energy and environmental management in small and medium-sized enterprises, they can improve their performance significantly and save in energy costs on the side. The notion that good cost management seems to be linked with energy management also supports this finding. In other words, good cost management can lead to interest in managing energy costs and thus additionally to better environmental performance.

However, it should be remembered that SMEs are a non-homogenous group of enterprises, which have a tendency not to prioritize energy management issues to a very high level. There are several barriers constricting investments in energy efficiency, particularly high risk aversion within the enterprises. Energy is mainly seen as quite a minor cost factor and energy savings as a risk that could put the whole production in danger. The saying "if it isn't broken, don't try to fix it" could be used to describe the current situation within the energy management of the SMEs. If energy prices will soar, the investment preference can become more appealing. Although most of the enterprises have a positive or neutral view about energy efficiency and renewable energy, it should be remembered that attitudes do not necessarily translate into action.

The level of technological knowledge and status of implemented systems can vary dramatically from one enterprise to another. What does this mean in terms of energy programmes and policy-making? Naturally, it is very hard to target this group effectively as one entity. Instead, different subgroups can be found (innovators, early adapters, early and late majority and laggards) which all need some sort of special attention. Egmond et al. (2006) state that "*one size does not fit all*" and that the target group should be well specified. In terms of energy goals of the EU and the SMEs, some more viewpoints should be included: industry-specific, local and regional culture, and also the effects from a network of various different stakeholders (suppliers, customers, employees, various governmental and non-governmental organizations. . .) all play a role in the diffusion of environmentally sound technology.

Because the SMEs are usually run by an owner-manager, efforts in reaching the SMEs should be directed there. Attending to the peculiarities and analysing the aspects of energy behaviour (Gynther et al. 2012) in entrepreneurs should bring energy efficiency and renewable energy closer to the core business of SMEs. Special attention should be paid to risk management, especially to reduce high risk aversion in energy investments. Usually investments in energy are made when the investment would have been done anyway. The importance of a single action for a greater significance needs to be addressed. This is merely a consequence from the large proportion of SMEs in all economic activities within the EU. To reach the targets, all energy consumers need to be involved, but the approach needs to be tailored well according to the target group.

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Chapter 13
The Diffusion of Green Technological Innovations and Stimulus: The Case of LUBEI Eco-Industrial Park in China

Li Guo

Abstract The green technology of LUBEI Eco-Industrial Park has undergone a process of evolution including a technology R&D stage, a technology improvement stage, a technology integration stage and a product innovation stage. The evolution of green technology of LUBEI Eco-Industrial Park in China during the last decade indicates a variety of green technological trajectories. The emerging green technology receives resistance from end-of-pipe technologies. The breakthrough of the path dependence by the existing technology is facilitated by changes in the 'selected environment' (the dynamic factors shaping technological evolution), i.e. favourable policies, auxiliary technological support, market environment, corporate culture and resources endowment.

Keywords Green technological innovation • Stimulus • Path dependence • Eco-industrial park, China

13.1 Introduction

China is facing the great challenge of green technological innovation in the post-financial crisis global economy. First, the drop of internal demand in developed countries caused a significant decrease in the volume of products exported from China to these counties. The fall of Chinese exports is being further aggravated by growing stringency of environmental requirements creating 'green barriers' to Chinese products in developed countries. Examples of 'green barriers' hampering the competitiveness of Chinese products include Green supply-chain standards, customers' appetite for green products and new environmental regulation directed

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to importers (e.g. requiring importers to identify and manage risks linked to the substances they manufacture and market). Second, developed countries pay more attention to the manufacturers' role in the economy than before, so possession of advanced environmental facilities and techniques will be a key factor in the more serious international competitions. Third, after suffering the crisis, the U.S. are preparing for a new round of economic development with emphasis on green-growth and low carb economies; the US will have the advantage of possessing a large stock of technology and capital invested in the 'environmental goods and services' sector, thus further challenging China's competiveness if the country does not improve its green technologies . However, due to the limited R&D capability of China's industries, a large portion of the environmental facilities and products must be imported from western countries. In other words, the current major problem facing China is how to self-develop green technologies and enhance the competence of Chinese enterprises in the international market.

Industrial ecology argues that the waste created from industrial production may be used as the raw materials for other facilities, and thus build a relationship of industrial symbiosis among them for mutual cooperation (such as waste reuse, transportation sharing etc.). At present, extensive practices in industrial symbiosis have been launched globally, such as Dupont in the U.S., Kalunborg in Denmark, Burnside Eco-Industrial Park (EIPs) in Canada and so on. It is widely accepted today that technical progress plays a decisive role in alleviating environmental problems. Efforts are thus being focused on the characteristics and determinants of green technological evolution in eco-industrial parks, considering the path dependence of existing technologies in the green technological evolution. LUBEI Eco-Industrial Park is one of the national eco-industrial parks authorized by the Ministry of Environmental Protection of China, which presents a different eco-industrial park model from other countries, and technological innovation in the Group illustrates the changes of the "selected environment" (the dynamic factors shaping technological evolution). Therefore, the study on the trajectory of green technology will provide insight into the interaction among various key actors including the government, firms, and research institutions as a regional innovation system in triggering of new technologies' adoption. The reinforcing mechanisms and path dependency properties which characterize the dynamics of the trajectories tend to reinforce the established technologies, and conversely, slow down the development of new technologies which, not yet widely diffused, have not been able to benefit from the same positive feedback loops.

The purpose of the article is to describe the evolution process of green technologies of LUBEI Eco-Industrial Park in China. The aim is to indentify the positive feedback loops which facilitate the green technologies to breakthrough the path dependence of the existing end-of-pipe technology. The status quo of China's green economy is demonstrated in the first part (Sect. 13.2), and the evolution process of China's environmental regulations is described in the next part (Sect. 13.3). The concept and framework of green technological innovation is presented in the third part (Sect. 13.4). In the fifth part, the path-dependence theory and its application are illustrated as the conceptual framework (Sect. 13.5). Next, a green technology is described: the joint production technology with ammonium phosphate, sulfuric acid, and cement (hereinafter referred to as "PSC" technology) (Sect. 13.6). The following section is an analysis of the green technological evolution process consisting of R&D, improvement, and integration of the process technology and product technological innovation (Sect. 13.7). The changes in the institutional and material environment that stimulated the PSC technology evolution are described in Sect. 13.8. Finally, a discussion is presented based on the description of the PSC technology and the analysis of the stimulus (Sect. 13.9).

13.2 Status Quo of Green Economy in China

With the fast development of industrialization and urbanization, corresponding environmental and social problems are preventing regional development. Behind the scenes, lots of measures aiming to close the gap between the economic and environmental are being put in place. How to realize economic growth, environment stabilization and social equity is one of the hot issues in the domain of regional governance. Presently, construction of eco-industrial parks is happening in the U.S., Canada, Japan, and other countries and studies on the theory of industrial ecology are being carried out. However, most literature on regional sustainable development and eco-industrial development focuses on the introduction of construction experience from western developed countries. Relatively little is known about the status quo of the green economy in China and even less on the ways to create environmental and economic win-win opportunities.

China is facing the Environmental Crisis. Firstly, China was ranked first place globally in terms of emissions per year of pollutants such as COD and SO_2.[1] Secondly, there is a significant structural pollution problem[2]: China's manufacturing industry is environmentally inefficient. COD emission from the food, paper, chemical, textile and chemical fibre industries account for 67% of China's annual total COD emissions. SO_2 emissions from the electricity, metal refinery, mineral, food and chemical industries account for 84.4% of China's annual total. Thirdly, emission levels fluctuate frequently and each pollutant substance follows a different pattern of fluctuations. In the first half of 2011, COD and SO_2 emissions decreased continuously, while nitrous oxide emission increased by 6.17%.[3]

What's more, China has a low rate of resource recycling compared with developed countries. Some developed countries have made remarkable progress in resource recycling; statistics shows that 1/3 of the steel output, 1/2 of the copper output, 1/3 of the paper products output all over the world comes from recycling.[4]

[1] Annual statistic report on environment in China 2003.

[2] http://www.china.com.cn/news/txt/2006-11/22/content_7389230.htm

[3] http://cn.reuters.com/article/CNEnvNews/idCNCHINA-4983020110928

[4] http://www.ce.cn/xwzx/gnsz/gdxw/200602/24/t20060224_6184793.shtml

However, resource recycling is just in an emergent stage in China. Energy utilization efficiency in China is 33%, the recycling rate of industrial water is 55%, and the recovery rate of mineral resource is 30%, which is respectively 10%, 25%, and 20% lower than the advanced level of developed countries. The comprehensive recovery rate of coal is about 30%; 500 million tons of waste steel, 200 million tons of waste nonferrous metals, and 1,400 million tons of waste paper as well as a large amount of waste plastics, glasses are not yet recycled each year.[5] The losses caused by the failure to recycle these renewable resources amounts to RMB 200–300 billion each year in China.[6]

13.3 Evolution of Environmental Regulations and the Emergence of Eco-Industrial Parks in China

Decades of high-speed economic development impelled China to turn into "the world's manufacturing plant". However, China's economy depends perennially on a development pattern characterized by high pollution, high energy consumption and low production, resulting ultimately in environmental devastation. A serious conflict exists between economic development and environmental protection, which is brought by the leaner economy pattern, the higher cost for the environment recovery remains in the future.

Figure 13.1 illustrates the evolution of approaches to environmental regulation in China -from commendatory to Economic-incentive based, and the changes in Government role -from Direct to Indirect. Emission standard regulation emerged very early in China's environmental laws, which emphasizes the end-of-pipe control of pollutants by regulating the consistency of pollutants. From 1982 to 2003, the pollutant charge system moved from the over standard charge to the coexistence of over standard charge and pollutant charge according to the pollutants types and amounts. Additionally, it adapted the pollutant consistency control into the combination control of the pollutant consistency and amount. From 1996, China introduced the ISO14001 environment management systems and standards (EMS) and started the trial of EMS certification nationwide, indicating the self-regulation environmental policies appearing in China. In 2002, the Cleaner Production Promotion Law was enacted in order to promote cleaner production, with cleaner production defined as the pollution reduction from resource, resource efficiency increase, and pollutant avoidance from manufacturing, service and product, so as to decrease the harm to the human beings and the environment. By 2007, China was facing much more significant international pressure to achieve the established goals of energy-saving and emission-reduction. Therefore the cleaner production and

[5] http://www.jieyue.net/html/lilun/page/homepage_show1195.htm

[6] Shenmin Li, A study on the industrialization for recycle and reuse of solid wastes in Shanghai, Master's Dissertation of Shanghai Jiaotong University, 2008.

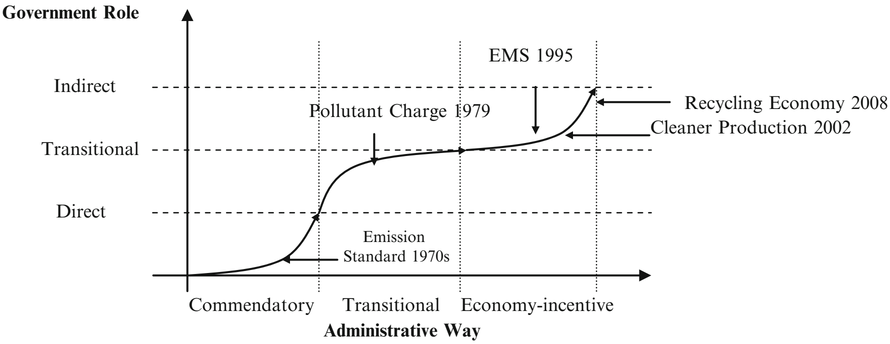

Fig. 13.1 Evolution of environmental regulations in China

recycling economy became much more popular than before, replacing traditional mandatory command and control regulations. In 2008, the Recycling Economy Promotion Law was enacted, in which recycling economy is defined as reduction, reuse and recycle in the processes of manufacturing, trade and consumption. Additionally, the Enterprises Income Tax Incentive Policy became effective for those products such as wind power, garbage power, regenerated water, and retreading tire.

The Eco-industrial park is viewed as an effective measure to implement cleaner production and recycling economy in China. Therefore, the National Eco-Industrial Parks Administration Regulation was enacted in 2003 and the Eco-Industrial Demonstration Parks Planning Manual was implemented in 2005. Later in 2007, an Eco-Industrial Park was defined in Eco-Industrial Parks Construction Manual as various plants or enterprises linked through the material or energy flow to establish industrial symbiosis. Thus, from 2001 to 2008, as many as 30 national eco-industrial demonstration parks were nominated by Ministry of Environmental Protection, amongst which the LUBEI Eco-Industrial Park was one of the early certified national eco-industrial parks.

13.4 Conceptual Framework

13.4.1 The Concept of Green Technological Innovation

Many facets of green technological innovation have important implications for the role of technological innovation on the balance of economic development and environmental protection. These facets can be classified as three perspectives (Table 13.1). The first is stakeholders' view. Huber (2008) and Kemp and Soete (1992) believe green innovation strategies include sustainable resource management, clean technologies, hazard material substitution, design for environment, product management, circular economy, industrial symbiosis and pollution control, which entail involvement from all stakeholders in the tech-economic system.

Table 13.1 Definitions of green technological innovation

Perspective	Common views	Authors
Stakeholders	New material, process or product entails the changes of infrastructure, competitive factors and other system component.	Kemp and Soete (1992)
	Green technological innovation involves techniques, economics, regulations, laws, organizations and human being behaviours.	Huber (2008)
Process Adaptation	Green technological innovation represents sustainable development process, with the purpose of the reduction of pollution rather than pollution treatment.	Hartje and Lurie (1984)
	In the meantime of decrease the environmental side-effects, the green technological innovation could provide the consumers and companies the new products and processes.	Fussler and James (1996)
	Green technologies emphasize the pollution reduction, making great difference from end-of-pipe techniques.	Faucheux and Nicolai (1998)
	Green technology is process change, including the optimization and adaptation of the current process and internal recycle.	Belis-Bergouignan et al. (2004)
	Green technology refers to the hazard waste reduction, waste recycle and resource development.	Bartlett and Trifilova (2010)
Public Products	The lack of the anticipation of private enterprises to the green technological innovation impedes the interests of technologies R&D and adoption.	Rennings (2000)
	The external features of green technological innovations result in the key roles of public policies.	Oltra and Saint Jean (2007)
	The reason of inadequate investment of the recyclable energy technologies lies on the price failure of fossil fuel.	Mowerya et al. (2010)

The second is process adaptation view. Belis-Bergouignan et al (2004), Bartlett and Trifilova (2010) and Hartje and Lurie (1984) propose that green technological innovation starts from pollution prevention and emphasize continuous process adaptation rather than pollution reduction techniques. The former entails larger investment in the short term but brings larger returns in the long term while the latter vice versa. The last is the “public goods” view. Mowerya et al. (2010), Rennings (2000) and Oltra and Saint Jean (2007) suggest that green technological innovation should be considered as a public good because it has positive externalities or overflows both in innovation and diffusion stages.

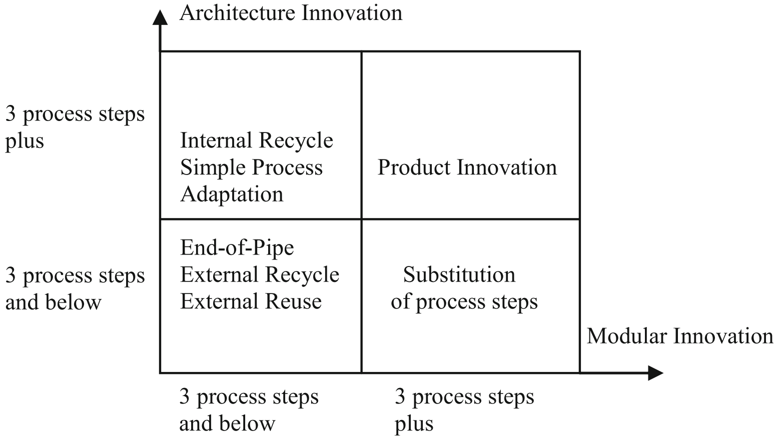

Fig. 13.2 Framework for innovation in green technologies

13.4.2 Framework of Green Technological Innovation

To develop an approach to the problem of why agents (enterprises) may stick to the costly end-of-pipe technology instead of adopting more efficient clean technology, a framework that clarifies the degree of innovation of green technologies is proposed in this section. Such framework is based on the interactions between product innovation and process innovation, between modular innovation and architectural innovation, and between incremental innovation and radical innovation (Fig. 13.2).

Product innovation refers to new product design for commercial purposes, aiming at promoting the quality and function of the products, i.e. the innovative design in the production. Modular innovation refers to the adaptation in one or more components no matter what its effects on other elements while architectural innovation refers to the modification in the way in which the components of a product are interrelated. Incremental innovation refers to minor modification of an existing technology system and radical innovation refers to an entirely new system to alter core components and system architecture.

Cleaner production refers to green technology with the characteristic of resource reduction and process control, emphasizing pollution prevention in the whole life cycle of the product. Pollution prevention measures include resource recycling, environment-friendly material utilization, and the adaptation of boiler design, etc. According to the innovation degree, cleaner production is divided into four types (Moors 2005). The first is ***1-S green technological innovation***, which refers to the green technology with only one process step change, including the production principle and excluding any other process changes. Industrial symbiosis and the reuse of unchanged waste belong to the type. The second is ***2-S green technological innovation***, which refers to the green technology with 2- or 3-step change, where the change of one process step leads to the former or latter steps change. The third is ***3-S green technological innovation***, which refers to more than 3-step change, indicating the change happens in major parts of the production process. The last is ***N-S green technological innovation***, which refers to the overall fresh production principle or plant design. Radical green technological innovation refers to cleaner production with major adaptation in the production, that is, 3-S and N-S innovations. As Belis-Bergouignan et al (2004) points out, radical green technological innovations (such as biofuel, solar power and chloride-free chemicals) will bring about change in production or lifestyle and therefore benefit the economic development in the long run.

13.5 Path-Dependence Theory and the Application in Green Technological Innovations

13.5.1 Path-Dependence Theory

Once a system has chosen a certain path (or technology trajectory) in response to a particular configuration of external uncontrolled factors, it will evolve according to this chosen path due to the self-reinforcing positive feedback mechanism of the system. Therefore it's hard for the system to shift to other path (or to have the chosen technology substituted by a more advanced one) in response to changes in external factors.[7] This is called "path dependence". Arthur (1989) carried on a ground-breaking exploratory study on self- reinforcement and path dependence in technology evolution. Due to certain factors, those primarily evolving technologies can benefit from economies of scale, unit cost reductions, learning effects, coordination effects and positive network externalities (wide distribution network, technological interrelatedness, increasing informational returns), thus making the techniques popular. In this way, the greatest self-reinforcement is realized. On the other hand, a better technique may enter an unfavourable cycle due to the lag step and even become locked into the status of non-effectiveness. North (1998) further explores the positive feedback from technology transition to system transition and applies the concept of path dependence to describe the influence of past performance on the present and future.

13.5.2 Path Dependence Model of Green Technological Innovations

Green technological innovations describe the transition from traditional end-of-pipe technology to cleaner production or from incremental cleaner production to radical cleaner production. The evolution process of green technologies has the

[7] The development of Radical green technology innovation is an uncontrolled factor for the system.

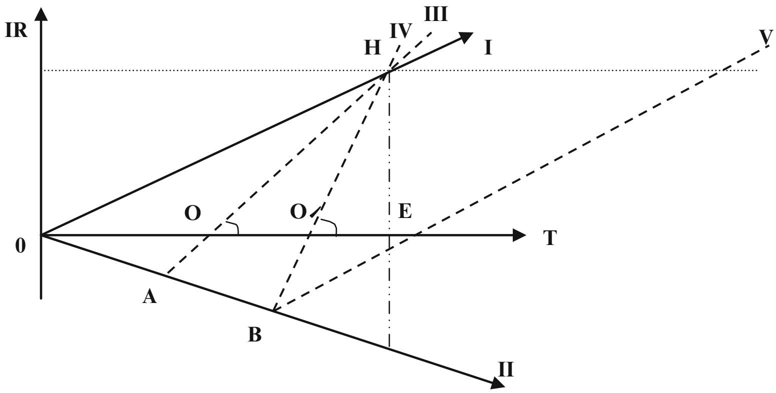

Fig. 13.3 Path dependence model of green technological innovations

characteristic of path dependence, for the mechanisms of return increase and self-reinforcement exist in the institution transition. The self-reinforcement mechanism becomes established once the system chooses a certain kind of path. Thus the past decision determines the present possible selection and the institution transition goes toward the fixed path. The institution transition may go into the virtuous cycle path and be rapidly upgraded; it may go down the wrong path and become locked into non-efficient status. To break the path dependence, external influences – such as radical green technological innovation- are often necessary to rebuild the system structure Based on the path-dependence theory, the path dependence model of green technological innovations (GTI) is established (Fig. 13.3).

Presuming the relationship between the increase return of GTI and time is linear, *T* represents certain time point; IR represents the increase return of GTI at a certain time point; a represents acceleration of GTI evolution (various paths start from the origin). Path I, Path II, Path III, Path IV and Path V respectively represent the evolution path of GTI. Path I indicates that IR remains as a positive value. Path II indicates that *IR* remains as a negative value. Acceleration reflects the change rate of *IR*, which can be expressed as,

$$a = tg\theta = \frac{\Delta IR}{\Delta T} \tag{13.1}$$

The formula displays two important characteristics. On the one hand, when the ΔT increases and acceleration (a) is invariable, ΔIR increases; On the other hand, when acceleration (a) increases and ΔT is invariable, ΔIR increases. For those system which chooses Path II, it is more difficult to reach the *IR* goal (i.e. point H) if it transits to Path IV at point B rather than if it transits to Path III at point A; because greater acceleration at the same time point is required when the system transit at point B ($\angle$HO/E > $\angle$HOE). If the system chooses Path V at point B and remains with the same acceleration ($\angle$HOE) as that of Path III, it will take more time for the former to reach the same *IR* goal (point H), which indicates that the later the ecological transformation of industrial systems begins, the more difficulties exist.

13.6 The Joint Production Technology with Ammonium Phosphate, Sulfuric Acid, and Cement

LUBEI Group represents the typical model of recycling economy in China. The company was established in 1997 and, since then, three highly related eco-industrial chains have formed, i.e. ammonium phosphate-sulphate-cement union production (hereinafter referred to as "PSC" technology), seawater's multi-utilization and salt-alkali–power union production. In 2004, LUBEI Group was certified as a national eco-industrial park and was part of the first group listed as "national environmental friendly enterprises" in China. LUBEI Eco-Industrial Park is the first eco-industrial park to form spontaneously in China. What's more, it's one of the few successful long-term operating industrial systems globally. Nowadays, it has reached several technical cooperation agreements with companies from the U.S., Japan and other countries.

LUBEI Group is the biggest ammonium phosphate, sulphate and cement union manufacture enterprise in China, and the biggest producer of phosphorus compound fertilizer and sulphate made from gypsum base at home. LUBEI Group has a production scale of one million tons of potassium sulphate compound fertilizer, 500 thousand tons of diammonium phosphate, 1 million tons of sulphate, 900 thousand tons of cement, 10 thousand tons of bromine, 60 thousand tons of Chlor-alkali, 1 million tons of raw salt and 150 thousand KW power generation capacities per year. It has 5,300 staff and fixed assets of RMB 5 billion. The sole sponsor of LUBEI Chemical Ltd. Company is LUBEI Group, whose stock share is still over 50% at present.

The green chemical plant and bromine plant serve as the core entities, while other plants serve as satellite entities, among which the material flows. PSC is a united processing equipment for phosphorus ammonium, sulfuric acid and cement, using wasted phosphorus gypsum, salt gypsum or natural gypsum to produce sulfuric acid and common silicate cement, sulfuric acid returns back to produce phosphorus ammonium; the waste of the upstream becomes the raw material of the downstream (see Fig. 13.4). The "one-water-multiple-uses" eco-industrial chain includes the following functions sequentially using the same water : (a) breeding by primary halogen water; (b) distilling bromine by intermediate halogen water; (c) picking up kalium magnesium by high layer halogen water; and (d) producing sulfuric acid and common cement by using wasted salt phosphorus gypsum. Therefore through the process of step-by-step vaporizing and purifying, the seawater is utilized comprehensively.

Presently, LUBEI Group has achieved strong environmental and economic performance. On the one side, LUBEI Group combines the three sets of production technologies of 300 thousand tons of Phosphorus ammonium, 400 thousand tons of sulphate acid and 600 thousand tons of cement. The waste gypsum from the production process of phosphorus ammonium is used to produce sulphate acid and cement; while sulphate acid returns to produce phosphorus ammonium. During the whole process, resources have been efficiently recycled, and no waste is emitted

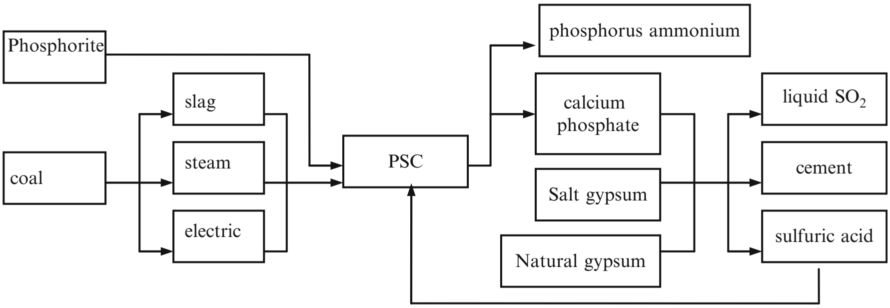

Fig. 13.4 PSC technology of LUBEI Eco-Industrial Park

outside the system, thus a relatively perfect industrial chain forms. Additionally, merely employing the PSC technique can save 6,000 thousand tons of iron ore (noting that the construction investment of a mine is RMB 30 billion); 1.3 million tons of lime stone (noting that the construction investment of a mine requires RMB 21 billion); thus reducing 20 million tons of phosphorus gypsum (noting that the construction investment of a 10-year landfill with the capacity of 200 million tons requires RMB 6 billion). At present, the Group has passed the ISO14001 environmental system certification and the audit of cleaner production, and has realized 100% solid wastes utilization for main devices, 100% solid waste treatment and 100% sewage treatment. The main devices have realized closed circulation and "zero" discharge, and the waste gas emissions and noise all conform to the regulated level. The costs of main products have lowered 30–50%, contributing up to 40% to the growth rate of annual output of the enterprise (Yu et al. 2007).

13.7 Green Technological Evolution Process

The green technology evolution process consists of R&D, Improvement, and integration of the process technology and product technological innovation.

Stage 1: Research and development of joint production of cement and sulfuric acid with gypsum

The predecessor of LUBEI Group was a small county phosphate fertilizer plant. In 1977, the plant was forced to stop production. Given the promising market of phosphate fertilizer (calcium sulphate), the plant technicians proposed an idea of using the waste salt gypsum discharged from the salt works for producing sulfuric acid. After a series of feasibility investigation and technical argumentation, a group of seven people took the responsibility of this national key scientific project in the sixth "Five-Year-Plan" for research and development of joint production of cement and sulfuric acid with gypsum. Through repeated laboratory research, device revision and industrial trials over 6 years, the plant had finally succeeded in producing qualified cement and sulfuric acid, and in 1983, the technology was certified at the national level. Because of the limited supply of waste salt gypsum for raw materials, in following 2 years, the group had cooperated with relevant research institutes and successfully developed the joint production of cement and sulfuric acid with phosphate gypsum and natural gypsum.

Stage 2: Improvements on the joint production of cement and sulfuric acid with gypsum

In 1985, the sulfuric acid and cement markets were oversupplied, so the joint production of cement and sulfuric acid with gypsum was presented with a dilemma. Technicians proposed a new plan for technical improvements. In this new plan, the urgently needed ammonium phosphate was produced (at that time, only 60% of market demand could be met by the production capacity), and the gypsum as the wasted material in producing ammonium phosphate was used as raw materials to produce sulfuric acid and cement, then finally, the sulfuric acid was used to produce ammonium phosphate. In this way, they could not only provide a market for sulfuric acid and cement, but also make use of the current technological advantages. After feasibility analysis, technicians found that the difficulty of improving former technology was in the handling of phosphate gypsum, a by-product of producing ammonium phosphate. Then, they cooperated with engineers from Nanjing Chemical Engineering Design Institute to design a device for compound fertilizer. Earlier in 1987, they succeeded in building a self-designed and self-installed integrated device for jointly producing sulfuric and 30 kt/a cement with 100 kt/a ammonium phosphate in slurry method and 20 kt/a gypsum phosphate, and put it into operation, becoming the first producer in China to have developed a joint production technology with ammonium phosphate, sulfuric acid and cement.

Stage 3: the upgrading and technical integration of PSC technology

Since PSC technology avoided the exploitation of pyrites and limestone and eliminated the environmental pollution resulting from the discharge of wasted phosphorous gypsum in producing ammonium phosphate, the relevant national department decided to upgrade and promote PSC technology. In 1990, supporting equipment was successfully tested for jointly producing sulfuric acid and 60 kt cement with 30 kt ammonium phosphate and 40 kt phosphorous gypsum. Before long, “three-four-six” green chemical PSC devices were successfully approved at the national level. At that time, such devices had already been effectively operated in the Group. However, due to the heavy demand for ammonium phosphate and cement in China, it was necessary to build a larger joint production device so as to promote PSC technology in more places. In 1997, with the support of relevant national departments, a PSC expansion project was formally started. In less than 2 years, PSC technology was expanded to the scale of jointly producing sulfuric acid and 600 kt cement with 300 kt ammonium phosphate and 400 kt phosphorous gypsum.

At the same time, in addition to PSC technology, LUBEI Group also developed “one-water-for-multiple-purposes”, cleaner power generation, as well as the co-generation of salt, alkali and electricity. On the one hand, based on the principle of gradual evaporation and purification of seawater, LUBEI Group built an industrial chain for fully utilizing seawater resources in following way: preliminary saline water for sea farming, intermediate saline water for extracting bromine, saturated saline water for making salt, bittern for extracting potassium and magnesium, wasted gypsum of residual salt from the ocean for producing sulfuric acid and jointly producing cement, seawater for cooling thermal power plant, and fine bittern for preparing caustic soda and chlorine at chlor-alkali devices. On the other hand, thermal power plant used low quality coal and coal gangue as raw materials, seawater for cooling, discharged residual coal for the mixed materials of cement, and preheated evaporating seawater for making salt at the salt works and also connecting the chlor-alkali plant. The chlor-alkali plant used millions of tons of the saline water resources from the salt plant and sent them directly to the chlor-alkali devices without conventional technology for making and melting salt. Thus, LUBEI Eco-Industrial Park realized the technological integration of PSC, "one-water-for-multiple-purposes", as well as the co-generation of salt, alkali and electricity.

Stage 4: the product innovation based on PSC technology

Since the present products such as phosphorous fertilizer and potassium fertilizer are substantially influenced by the market and many products in the present industrial chain can be further processed, LUBEI Group has made efforts to make product innovations based on PSC technology. For example, the company strengthened the deep processing of bromine products and developed high value added bromine series coolants, anti-knock substances and fire extinguishing agents, etc.. Also, for example, based on the sulfuric acid produced by the current industrial chains, the company renovated the Devices III, IV and VI, which had previously been discarded as worn-out equipment, to produce titanium dioxide which is both environmental friendly and of high quality, and has become one of the most profitable products of the company.

13.7.1 The Path Analysis of Technological Evolution

From its history of technological evolution, we can see that LUBEI Group has undergone four stages in technological transition by implementing technological innovations from the initial idea of making sulfuric acid with salt gypsum to the research and development of PSC technology, tests and operation. LUBEI Eco-Industrial Park is also making continuous progress with the transition of technologies. The technological evolution of LUBEI Eco-Industrial Park is shown in Table 13.2.

Figure 13.5 represents the technological trajectory of LUBEI Eco-Industrial Park. The trend indicates that its technological evolution, technology integration and product innovation are critical for future development of technology.

Table 13.2 The phases of technological evolution of LUBEI Eco-Industrial Park

Stage	Period	Primary technological innovations	LUBEI Group development status
Stage 1	1977–1985	Joint production of cement and sulfuric acid with gypsum	Obtained fund of RMB 400 thousand for experiments, and founded sulfuric acid plant
Stage 2	1985–1989	Joint production of cement and sulfuric acid with phosphorous gypsum	Solved the problem of sulfuric acid sales
Stage 3	1989–1997	PSC expansion project PSC, seawater "one-water-for-multiple-purposes", and the co-generation of salt, alkali and electricity	In 1991, LUBEI Group was founded; in 1996, Shandong LUBEI Chemical Co., Ltd went public through an initial public offering
Stage 4	1998–present	Product innovations in bromine series products, titanium dioxide, ecological power, etc..	In 2003, LUBEI Group was valuated as the demonstrative park of ecological industries at the national level

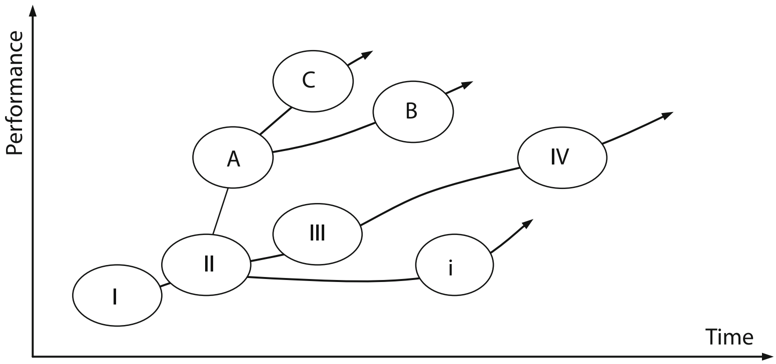

Fig. 13.5 Trajectory of technological evolution of LUBEI Eco-Industrial Park. *Note*: I represents the joint production technology for producing cement and sulfuric acid with gypsum; II represents PSC technology for capacity of 3:4:6; III represents PSC technology for capacity of 5:6:8; IV represents PSC technology for capacity of 15:20:30; i represents production technology of Titanium Dioxide; A represents for "one-water-for-multiple-purposes"; B represents co-generation of alt, alkali and electricity; C represents innovation of bromine series products

The concept of the technological trajectory (Nelson and Winter 1977) is applied to present an ordered, cumulative process of technical change by which a given technology tends to move towards its highest possible level of efficiency. According to Arthur's Theory, the diffusion of the green technology in LUBEI Eco-Industrial Park has benefitted from a long learning process, considerable economies of scale in production and a multitude of positive network externalities (wide distribution network, technological interrelatedness, increasing informational returns, etc.).

Table 13.3 Key factors influencing technological evolution

	Stage 1	Stage 2	Stage 3	Stage 4
Encouragement Policies	Fund provided by the state for scientific research	Supported by local government	Development opportunity of cross-century projects	State environment development strategy
Technology Support	Independent research and development	Cooperative development	Consultancy	Diagnosis by experts
Market Environment	Lack of sulfuric acid supply	Oversupply of sulfuric acid	Lack of power supply	Oversupply of sulfuric acid and cement
Corporate Culture	Shutdown recovery	Utilization of wasted resources	Win-win in economy and environment	Win-win in economy and environment
Resources Endowment	Salt gypsum	Phosphorous gypsum	Salt works, seawater	Existed industrial chain

13.8 Analysis on the Dynamics of the Technological Evolution of LUBEI Eco-Industrial Park

LUBEI Eco-industrial Park is built on the interacted factors of policy environment, external technology support, and so on, and its technological evolution is dependent upon the improvement of its competency. The dynamic factors of its technological evolution constitute the selected environment, comprised of five aspects: encouragement policies, technological support, resources endowment, corporate culture, and market environment, etc. (See Table 13.3).

13.8.1 Encouragement Policies

In LUBEI Eco-Industrial Park, all new ideas, corporate strategies (independent research and development or cooperation) and new technology applications are fully supported by government. In 1977, the idea proposed by the development group to produce sulfuric acid with gypsum was supported with RMB 400 thousand as a project financed by the state according to the sixth "five-year plan". Using this funding, the development group launched 159 rounds of revisions on the devices, more than one hundred rounds of sampling, and finally succeeded in developing the production technology for sulfuric acid. In 1997, at the moment LUBEI Group was to implement PSC expansion, the State council made a critical approval reply, which provided a solid groundwork for the upgrading of technology at LUBEI Group in terms of capital, technology and policies. Therefore, the uncertainty of external environment, the difficulty and complexity of technological innovation projects are major obstacles for the enterprise to carry out technological innovations. It is also the case for the technological innovations in environmental protection, and the government has played an indispensable role in it.

13.8.2 Auxiliary Technological Support

At each phase of technical evolution, LUBEI Group relied on the assistance and participation of research institutes. At the earlier stage of PSC technology, LUBEI Group had a close cooperation with Nanjing Chemical Engineering Design Institute. At the stage of PSC technology integration, LUBEI Group completed its strategic objective in ocean chemical engineering using the support and with the assistance of research institutes. At the stage of product innovation, LUBEI Group started a campaign inviting 17 academics to provide diagnosis and consultancy on the development of the company in order to find out problems that existed and help the company to determine further objectives (Diao and Su 2008). So, it can be seen that the symbiotic evolution is a complicated system project, and given the limited capability of the enterprise itself, it is critical for it to look for external technology support to realize technological evolution.

13.8.3 Market Environment

Technological evolution as symbiotic evolution of industry aims to achieve both economic objectives and environmental objectives, and it is influenced by the market environment of its products. The research and development of joint production of sulfuric acid and cement with gypsum was undertaken at the right moment, when the enterprise demanded sulfuric acid as the raw material, and when the market of sulfuric acid was tight, so PSC technology became a useful an innovative technology to produce ammonium phosphate with the raw materials other than the sulfuric acid. Later, due to the market demand for ammonium phosphate and the oversupply of sulfuric acid, LUBEI Group made innovations on its technology of joint production of sulfuric acid and cement with gypsum and thereby initiated its PSC technology.

13.8.4 Corporate Culture

During the four stages of technological evolution, LUBEI Group stressed that the double win in terms of environment and economy is shaped by its corporate culture. LUBEI Group underwent a transition from the economic orientation to the double win in terms of both environment and economy with its utilization of waste in the salt fields due to the lack of sulfuric acid as a raw material to the "one-water–for-multiple-purposes" of seawater, and then to the ecological power generation. It was just because LUBEI Group was earlier than other domestic enterprise in realizing the forthcoming transformation of corporate culture that it was driven to implement, upgrade and expand PSC technology, and thereby increased its economic and environmental benefits and elevated its competency among its counterparts in the same industry.

13.8.5 Resources Endowment

PSC technology of LUBEI Eco-industrial Park had a close relationship with local resource endowment. The idea of joint production of sulfuric acid and cement with gypsum was based on the local abundant gypsum wasted in the salt fields. In the stage of technology integration, "one-water–for-multiple-purposes" of seawater and the co-generation of salt, alkali and power were also based on the abundance of seawater. So the natural endowment provided a platform to LUBEI Group for its technological evolution.

13.9 Conclusions

Technological innovation has been constrained by factors such as technological opportunities, circumstances for choice making, and learning effects, and easily falls into an inextricable "lock-in" state. As more alternative technological trajectories are available through the process of symbiotic evolution, once the circumstances are favourable to a specific environmental technological concept, the technological inertia and the path dependency will prevent the learning effect from motivating innovation, thus delaying the long-term technological paradigms and technological trajectories. Technology developments in preventing pollution, the paradigm of symbiotic technology will be surely replaced by more advanced technologies and shifts to a new technological trajectory. Based on this, the article studies the technological trajectory in industrial symbiosis, explores the rules of technological alternation, and answers the question as to which direction technology will develop in industrial symbiotic evolution.

The technological trajectory in LUBEI Group relies on the knowledge base developed within the Eco-Industrial Park, because the technicians have a common perception of the problems posed and the ways in which they may be solved, and of the development potential of each individual technology. Experience gained over time in production or in the use of the technology, and dynamic scale effects, then help to gradually improve the technical characteristics and economic performance of the technology, and strengthen advancement along specific trajectories. While, the path dependency properties of established technologies hinder the development of new technologies that have not benefit from the same reinforcement mechanism, in LUBEI Group's case, a technological breakthrough accompanied by a favourable development of the selection environment is the stimulus of the diffusion of green technological innovations. The changes in the selected environment not only guarantee breakthrough of the technological "lock-in", but also lead to the creation and gradual expansion of niche markets, through the learning process. The possibility of creating a technological monopoly based on the new trajectory, facilitated by the existence of increasing returns to adoption.

China is facing critical demands to provide green technological innovations in the post-crisis era. Due to the low level of the overall technology systems and limited R&D capabilities of domestic enterprises, techniques and equipment must often be imported from developed countries in order to promote economy development in the post-crisis era. Therefore, the key issue at present is how to enhance the competitiveness of manufacturing industries and their export products through independent green innovations. Through the analysis on green technology trajectories in China, the suggestions are proposed as follows. First, it is necessary to distinguish the mechanism and regulations of green technological innovation, grasp the window of opportunity and increase the R&D investment on advanced green technologies in order to seek the first-mover advantage in international markets; Second, public policies, market drives, organizational cultures and other stimulus play key roles in the green technological evolution. Therefore, it is critical to make clear of the mechanism of the stimulus and make full use of the stimulus of green technological innovation in order to avoid a "low-efficiency technology trap".

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Chapter 14
The Practice of Innovative Energy Systems Diffusion in Neighbourhood Renovation Projects: A Comparison of 11 Cases in the Netherlands

Thomas Hoppe, Hans Bressers, and Kris Lulofs

Abstract The diffusion of clean energy technologies is important to foster Green Growth. In the Netherlands the housing sector has considerable potential to increase energy efficiency by applying innovative energy technologies (IES). In this chapter we aim to answer the question of which factors explain the successful application of IES in neighbourhood renovation projects. Our research involves a comparative design, looking at 11 case studies. Comprehensive data collection was carried out, including 70 semi-structured interviews. We found that in only 3 out of 11 cases were IES successfully applied. Ambitions were reduced as the projects progressed. The main results of the analysis identify three factors that are positively related to IES application: policy instruments, housing associations' organizational characteristics, and inter-organizational collaboration. The results of our analysis suggest that more policy efforts are needed to deploy IES in residential areas over a wider scale. This is important to facilitate Green Growth.

Keywords Built environment • Climate change mitigation • Public housing • Renewable energy technologies • Sustainable cities

14.1 Background and Problem Definition

Accelerated development and wider diffusion of clean technologies and related knowledge are key strategies to foster green growth. There is considerable potential for further development and deployment of renewable energy, energy efficiency

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and other low-carbon technologies. Applying these measures brings important advantages: increased energy security, reduced energy costs, and an improved environment. It will be critical to tap into this potential to green both the energy sector and other sectors that consume great amounts of energy (OECD 2010).

The built environment is one such sector, which theoretically provides ample opportunity for significant energy conservation. The application of such technical measures as insulation and innovative, high-yield heating systems means that the energy efficiency levels of dwellings can be dramatically improved. Similar to other OECD countries, the built environment in the Netherlands accounts for approximately one-third of total domestic greenhouse gas emission. Of this, the majority comes from the residential sector where it primarily stems from decentralized combustion of natural gas (in houses) and combustion of coal in power plants for generating electricity. In Dutch houses gas is used for space heating, water heating and cooking. Electricity is used for lighting and domestic appliances.

The housing stock in the Netherlands is rather old. The energy quality of these old houses is dramatically poorer than those that have been built more recently. To a large extent this is because legislation on energy efficiency was only implemented after 1975. Before then there were no standards prescribing insulation and the installation of high-yield condensation boilers (Jong et al. 2005). Since 1975, regulation of the energy quality of new houses has gradually become more ambitious, even though it only impacts houses in their construction phase. Legislative standards and subsidies are largely responsible for both increased energy efficiency and the adoption of innovative energy system (IES) in new-built houses. However, little effort has been made to encourage the adoption of IES in the current housing stock. By ‘innovative energy systems’ we mean renewable energy technologies and energy efficiency technologies that clearly differ from conventionally used technologies to improve the energy performance of houses.

Technically speaking, adequate solutions are available to solve the problem. Domestic energy conservation up to a level of 90% is currently feasible (Trecodome 2008). However, it is the owners and occupiers who decide whether the application of such technical measures is desirable. When owners or occupiers consider renovating their homes they hardly prioritize energy efficiency, especially when energy costs are but a small part of the total cost of living (Sunnika 2001; Lulofs and Lettinga 2003; SenterNovem 2005). Moreover, the owners and occupiers have needs that are perceived as more urgent in regard to other issues, such as comfort, health, and a return on investment.

Renovation projects in residential areas are an opportunity to target the installation of IES in large numbers of houses, since the estates are commonly in single ownership and they offer economies of scale. Nonetheless, this implies that it is important to target efforts on local stakeholders in order to negotiate trade-offs. These efforts can influence decision making by house owners and occupiers.

In this chapter we aim to answer the question of which factors explain the appliance of IES in renovation projects in residential areas. Our focus lies on residential areas characterized by relatively low-value houses, predominantly owned by semi-public housing associations. We assume that six factors are relevant to explain the retrofitting of IES: the influence exercised by policy instruments (more specifically in the domain of climate policy), the influence exercised by local governments, the influence exercised by housing associations (who own housing property), the influence of collaborative efforts between actors, cognitive cohesion between actors, and the influence of contextual factors.

We apply both qualitative and quantitative research methods in a comparative design. Our analysis is relevant in the context of the urgent policy challenge of meeting the 2020 Dutch climate mitigation goals, which include a 14% renewable energy share in the total energy mix, and 46–50% energy conservation in the built environment.

Our paper is structured as follows. Section 14.2 presents a literature review of IES as they are currently applied in residential areas. Next, Sect. 14.3 describes the institutional context, presenting a list of the main actors, their interests, resources, and the ways in which they interact with each other. Section 14.4 presents a theoretical framework. The research design and methodology are addressed in Sect. 14.5. Section 14.6 reports the results of the analysis. The final section addresses the conclusions of the empirical study, as well as the position of this research in relation to Green Growth.

14.2 Policy Instruments and the Application of IES in Residential Areas

Since the First Oil Crisis of 1973, many programs have been implemented in an attempt to conserve energy in the residential sector. Since the late 1970s experiments in The Netherlands started with the utilization of renewable energy technologies, such as wind and solar energy. Although the environmental and long-term economic benefits are known, many uncertain factors – such as long development times, uncertainty about market demand, social gains and the need for change at different levels of organizations and the wider social and institutional context – hinder their widespread adoption. In fact, a whole range of factors work against the introduction and diffusion of alternative energy technologies. The appropriate conditions for new markets are hardly present and clearly hamper the diffusion of environmentally preferable technologies (Kemp et al. 1998). This is also true of the built environment, especially in residential areas.

Based on exploratory case studies in urban renewal projects in the Netherlands, Van der Waals et al. (2003) claim that environmental goals – such as energy efficiency – are considered of secondary importance by local stakeholders. Moreover, great policy ambitions that were been set in the start of a project remain unfulfilled when the project is finished. The lack of useful and adequate policy instruments on the local level was mentioned as the main reason (Van der Waals et al. 2003; Hoppe et al. 2010). For instance, in contrast to newly constructed buildings, there are no legal standards for the renovation and maintenance of the existing stock (Hoppe and Lulofs 2008). This, however, is not just a Dutch problem as it also applies to other Western European countries (Elle et al. 2002). Moreover, owner-occupiers in the existing residential sites are expected to act voluntarily and to cooperate with other actors. All levels of government try to encourage IES by implementing economic policy instruments and providing adequate information (Hoppe and Lulofs 2008). In this regard, covenants are also implemented but can be considered as only little effective, since only those parties are attracted who are already motivated and involved, and compliance by local actors is rather poor (Balthasar 2000; Van der Waals et al. 2003). Evidence from Swiss policy evaluation shows that close cooperation between different (levels of) government does benefit program effectiveness (Balthasar 2000). In the Netherlands intergovernmental governance is used as an incentive to improve local climate policy efforts. However, there are only moderate indications of its effectiveness (Arentsen 2008; Hoppe and Lulofs 2008).

More information on policy strategies and instruments is provided in Sect. 14.3, which addresses the institutional context of renovation projects in residential areas. We discuss this topic because we believe that without understanding the basic rules and power relations in local institutional contexts any analysis of the effectiveness of policy instruments would be useless.

14.3 The Institutional Context of Renovation Projects in the Netherlands

In order to understand the environment in which the energy efficiency of existing houses can be improved it is necessary to gain insights in the roles of the local actors, their interests, the resources they possess and exchange, and the ways they interact. Opportunities for the application of innovative energy systems in the current housing stock lie in large-scale renovation projects in relatively old, post-War neighbourhoods.

The houses and their environments are often characterized by poor-quality, obsolete physical construction. An additional characteristic is that the poor-quality buildings are accompanied by a poor-quality social structure. The neighbourhoods are characterized by a high degree of unemployment, above-average crime rate and a large proportion of ageing residents. Renovation projects are primarily meant to improve both social and physical structures in neighbourhoods. The application of innovative energy systems is considered not more than a secondary objective in that endeavour. The houses in the neighbourhood are for the most part owned by one or more former public or semi-public housing associations. Until 1995 housing associations in the Netherlands were public or semi-public institutions, largely financed by central government. In 1995 they were liberalized, receiving financial decision-making autonomy and large lump-sums of money from national government. However, the housing associations maintained their key public goal of providing quality housing to those in society who cannot afford to buy their own home (Koffijberg 2005).

A lot of decision making is involved when a large-scale neighbourhood or building block renovation plan is being scheduled. Agreements are often laid down in covenants that cover agreements of intent between local governments and housing associations. Local governments are able to exercise influence and encourage the housing associations to take up energy efficiency goals, by making tradeoffs, while strategically using urban renewal subsidies and legal permits. Nonetheless, the local authority remains firmly dependent on the willingness of housing associations to cooperate. Housing associations have the most significant resources since they own the housing stock and have the financial reserves to make the investments required. Additionally, in renovation projects, legal consent is required from the tenants who live in the houses. The legal standard is that at least 70% of the tenants must approve the renovation project plans. This statutory approval rate gives the tenants some room to negotiate with their housing association. It is not surprising, therefore, that housing associations take great pains to persuade their tenants to get their plans approved. However, local governments and tenants have few means to negotiate with housing associations in order to encourage them to install technical equipment that would significantly improve energy efficiency in the houses. The power imbalance is key to the housing association's advantage when decision-making is at stake. In the end the housing associations decide – whether or not and if so, how much – to invest in energy efficiency (Hoppe and Lulofs 2008).

Parts of the post-War neighbourhoods also contain private home owners. The owner-occupiers are often former tenants of the housing association. The housing associations sold them their houses in the years prior to the renovation project. When renovation projects are scheduled and many owner-occupiers reside in the neighbourhood, the housing association(s) and municipality are often inclined to have them participate in the project. Compared to the public housing occupants, the owner-occupiers can only participate if they decide to invest their own funds (housing associations make the investments for their tenants, and are often only compensated by a small monthly rent increase, if they are compensated at all). Loans and mortgages are often so high that (low income) owner-occupiers have problems acquiring them. Access to loans and mortgages represents a serious barrier to persuading house owners to invest and participate in the neighbourhood renovation project (Clinch and Healy 2000). Even when national government offers additional means to further encourage this group – by fitting 'meters' in houses to measure energy usage, information campaigns, provision of insulation packages, energy audits, 'green mortgages', and subsidy schemes – the actual effect is marginal. In short, there are several institutional barriers that hamper the large-scale adoption of technical equipment to encourage energy efficiency in existing housing (Hoppe and Lulofs 2008).

14.4 Theoretical Framework

Several theoretical insights are useful in showing us how to perceive and explain the phenomenon of energy conservation in the existing housing stock. These theoretical insights have their origin in a variety of disciplines, such as environmental economics and environmental psychology, diffusion-of-innovation studies, science-and-technology studies and policy implementation. The last two fields are especially useful thanks to their emphasis on the application of innovative measures and their relatively widespread use in local settings.

Insights from diffusion-of-innovation studies allow us to examine the processes that underlie the dissemination and acceptance of innovative concepts in social communities (e.g., Rogers 1962; Granovetter 1973, 1978; Burt 1987). Innovative measures need to be accepted and adopted if we are to approach a sustainable society, which also involves the replacement of fossil fuels by sustainable alternatives. It turns out that this is rather difficult, however, since conventional technologies, such as those surrounding fossil fuels, are 'locked in' by means of a cluster of socially accepted system factors that represent barriers to innovative alternatives, such as sustainable energy carriers (Unruh 2000). Traditionally, innovation studies – and to a lesser degree science-and-technology studies – focus on the supply side of the market and initiating processes of diffusion and change, in contrast to the demand side of the market, seeking to maintain a process of diffusion and change. The diffusion process is further complicated by the fact that the early market customers have already adopted the concept – the so-called exemplary minority (Bressers 1989) – whereas mainstream market customers still remain to be convinced. Moreover, the adoption of IES is considered a co-evolutionary process, involving opportunities and barriers deriving from both technological and social factors (Dosi 1982).

It is very difficult to convince the majority of potential adopters. Conventional behaviour and the existence of institutional barriers (many due to poor integration of climate policy with sectoral policies) limit further adoption. A facilitating institutional setting is considered a precondition for continuing the process of acceptance. There are several strategies that encourage the process of acceptance, some of which have been incorporated in policy strategies and instruments. Such incentives are widely implemented in contexts where one has to deal with serious setbacks with several competing constraints originating in traditional policy domains, such as housing and spatial planning. This means that the successful implementation of policy instruments aimed at the diffusion of innovative or sustainable energy equipment is seldom self-evident.

Policy implementation studies examine the factors that explain the effectiveness of policy implementation and its products. Implementation studies originate from the 1970s and are characterized by a broad range of theoretical developments (O'Toole 2000). During the 1990s attention became centred around a few topics, such as 'policy networks' (Marsh and Rhodes 1992; Bressers 1993; Dowding 1995; Smith 1997; Klijn 1996; Börzel 1998; Bressers and O'Toole 1998), 'network management' (De Bruijn and Ten Heuvelhof 1995; Kickert et al. 1997), and the prospect that the horizontal 'governance' model would come to replace the hierarchic-traditional 'government' model (Bressers and Kuks 2003). In order to encompass the broad continuum of theoretical developments in environmental implementation studies, Bressers (2004, 2009) developed the Contextual Interaction theory, which assumes that the choice and implementation of policy instruments depends on the cognition, motivation, and resources of local actors, the distribution of power between them, and the way they interact with each other in a local policy arena. Furthermore, the theory places strong emphasis on contextual factors. It also holds that environmental policy is seldom prioritized in the list of preferences held by local actors in the local context. The study presented here uses many elements of the Contextual Interaction theory. The relevance of the theory to the domain of energy conservation in existing housing sites is that it involves the implementation of a type of environmental policy, in this case as an incentive to encourage energy conservation. The Contextual Interaction theory facilitates a systematic analysis of environmental policy implementation processes.

The insights presented in the previous sections led us to choose an approach that applies a number of theoretical viewpoints. We preferred a multi-theoretical approach to a mono-theoretical one since we assume that a multi-theoretical approach will lead to a larger explained variation. For that reason, it is useful to specify several clusters of independent variables in order to test them at a later stage. We aim to discover which cluster of independent variables delivers the most powerful explanations. We present a graphical view of our research model in Fig. 14.1.

All clusters of variables are subdivided into a number of different items. These items are used as indicators of the specific explanatory model of the particular independent variable. The six clusters of independent variables concern: (1) the use of policy instruments in the domain of climate policy; (2) organizational characteristics of the local government; (3) organizational characteristics of the housing association; (4) inter-organizational collaboration between actors; (5) cognitive cohesion; and (6) physical, economic and institutional characteristics of the project context. This last cluster was added to the research model as a contextual component along with the other variables, which are more theoretically oriented. Without specific knowledge of the project context it is useless to analyse the outcome of policy implementation processes. Contextual factors are used as control variables; hence the dotted line in Fig. 14.1.

Below we survey the main hypotheses in the research model. The hypotheses concern the main propositions in the analytical framework. Since the main independent variables might be operationalized as clusters comprising a number of indicators, the sub-set items are mentioned, too.

– The greater the number of policy instruments in the climate policy domain that are being implemented in the local project arena, the more likely that IES will be applied in the renovated housing stock. The variable comprises the following items: the presence of local or regional energy conservation covenants, the use of subsidy schemes, and the use of communicative policy instruments.

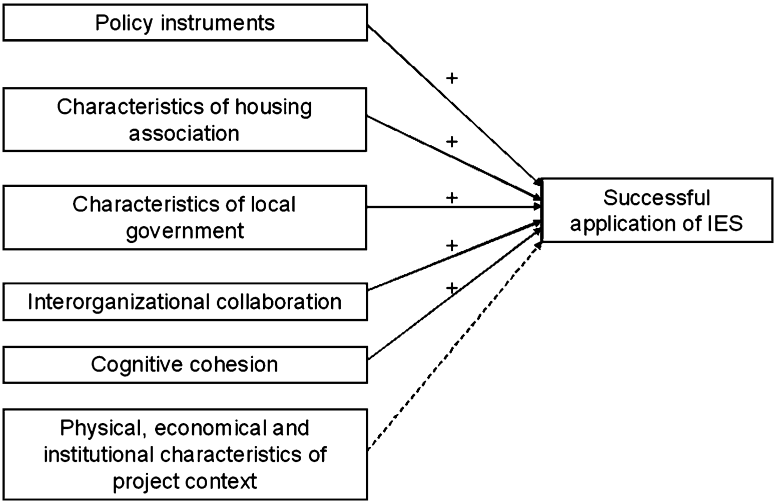

Fig. 14.1 Graphical presentation of the research model

- The more the organizational characteristics of the local authority favour energy conservation, the more likely that IES will be applied in the renovated housing stock. The variable comprises the following items: orientation toward environmental problems, the presence of formal energy conservation policy, personal capacity, the presence of advocates of energy conservation in housing, the degree of organizational tuning, the political orientation of the local officials, the size of the appropriate budget provided by national government, and the size of the municipality.
- The more the organizational characteristics of housing associations favour energy conservation, the more likely that IES will be applied in the renovated housing stock. The variable comprises the following items: orientation toward environmental problems, the presence of formal energy conservation policy, personal capacity, the presence of advocates of energy conservation in housing, the degree of organizational tuning, the financial position (company capital) and the size of the housing stock owned.
- The more inter-organizational collaboration efforts that are undertaken, the more likely that IES will be applied in the renovated housing stock. The variable comprises the following items: the presence of opinion leaders, the frequency of visits to professional meetings on the subject, and the size of the project configuration over time.
- The more cognitive cohesion that exists between organizations, the more likely that IES will be applied in the renovated housing stock. The variable comprises the following items: cohesion in respect of the environment and sustainable development, cohesion related to the adoption of technological innovation, and cohesion in respect of the national climate policy strategy.

The ‘project context’ cluster comprises the following control variables: division of ownership rights in houses on site, total investment per house, lengthening of the exploitation term per house, type of heating system, distance to city heating facility, equilibrium in supply and demand in the market for public housing, initial energy quality of houses on location, type of house, number of houses to be renovated on site, address density, degree of public participation in the project, and degree to which energy conservation policy is institutionalized in the project’s management structure.

14.5 Methodology

In order to answer our research questions we conducted a comparative analysis comprising 11 case studies. We focused on the retrofitting of IES in local neighbourhood refurbishment projects. In this section we describe important aspects of our research design and methodology: data collection, data treatment, and data analysis.

14.5.1 Data Collection

When the study started, only quantitative data were available from a previous study on ambition-setting and energy conservation on existing housing sites (Hoppe et al. 2011). After the case selection and a pilot study were finalized, we contacted persons involved in the housing sites of interest. We made partial use of the ‘snowball’ method to contact other key persons in the cases, after which dates were set for in-depth interviews. Forty on-site interviews and 30 telephone interviews were conducted. Some additional documentation on the cases was traced before the interviews were conducted; more was found after access was provided by the interviewees. The project documents found included formal policy documents, advisory reports, annual reports, specific information papers, websites, feasibility studies and geographical maps of project locations.

The group of interviewees featured predominantly persons from the following professions: project manager at the housing association, project leader in the local authority (urban renewal, property development), civil servant dealing with environmental or energy/climate affairs in the local authority, and energy associate in the housing association. The high incidence of these professions was beneficial to the researcher for three reasons: (1) most interviewees were involved in decision making on the subject of energy efficiency in the projects of interest; (2) they were often involved in the project for relatively long periods, meaning they were very knowledgeable and experienced; and (3) they possessed good networks with many contacts of interest to the researcher. Finally, it is worth noting that most interviewees were males in the age category 40–50, with higher education (most frequently in civil engineering).

14.5.2 Data Treatment

The quest for comparison of 11 cases meant that analysis by qualitative means alone was out of the question. The number of cases also required quantitative analysis. Hence, data treatment was of great importance to the comparative analysis.

The recorded interviews were written down in transcription reports. It was decided to use near-literal transcription reports in order to make full use of the richness of the data collected. After data collection, transcription reporting, supplementing ambiguities in data sources and story lines, case histories were constructed. After the case histories were completed, qualitative data were quantitated (however, many quantitative data were already present in the cases). Ten-point scales were constructed and scores were assigned per case. A data matrix was thus created, meaning that careful attention had to be paid to case histories and case-specific data in order to fill in the data reliably. A code document was designed for construct validation and reliable score assignment. This process had to be carried out in a reliable manner, so all score assignments were augmented with textual argumentation. Subsequently, the score assignment was replicated to check reliability and consistency.

14.5.3 Data Analysis

Data analysis in the comparative research design was characterized by phasing, the use of different types of research methods, and the use of different types of data. The analysis featured both qualitative and quantitative methods to allow the cases to be compared. Qualitative and quantitative methods were used to compensate, meaning that ‘mixed methods’ have been applied, a methodology that derives from an epistemologically pragmatic stance (Johnson and Onwuegbuzie 2004). The objective of applying both qualitative and quantitative methods in comparative research is to confirm analytical results where possible (triangulation), improve the researcher’s interpretation, and optimize the sample (inter alia).

The qualitative analysis features crisp-set qualitative comparative analysis (csQCA). QCA (Ragin 1987, 2000) is a method designed to bridge the divide between variable-oriented and case-oriented comparative research designs. Variable-oriented case analyses suffer from the disadvantage that the analysis is narrowed down to a limited number of variables, whereas cases often provide a ‘thick description’ with a large number of variables. Variable-oriented case analyses leave little room for specific cultural and historical aspects. The disadvantage of case-oriented analyses is that causal patterns cannot be compared between cases. QCA positions itself between the complexity of case-oriented approaches and the generalization of variable-oriented ones. The method is of particular importance when one wants to compare causal patterns with a medium-sized number of cases (10–50). Both qualitative and quantitative data can be applied. After coding the data into binary data – either present ('1') or non-present ('0') – a data matrix is developed. In QCA a data matrix is called a 'truth table'. Truth table analysis allows researchers to make statements about necessary and sufficient conditions that arise if a certain dichotomous social phenomenon is to occur. QCA also enables the researcher to make statements about combinations of conditions that enable the occurrence of a social phenomenon under investigation. QCA results – i.e., such causal patterns as are found – enable the researcher to either develop theories or to test or build upon existing theories. Here QCA is applied in light of the richness of information on the cases and because the dependent variable is a dichotomy: an innovative energy system is either applied ('1') or not ('0'). The software package fsQCA 2.2 (Ragin et al. 2007) was used to compute the analysis.

Bivariate correlations were computed to confirm the results from the QCA. The small number of cases (n = 11) necessitated the use of a 90% confidence interval. Since we predicted the direction of the correlations, one-tailed tests were computed. Regression analysis could not be performed because of the dichotomous dependent variable.

14.6 Results

This section presents the results of the comparative analysis. We have chosen to present the results in stages. First, important data are presented per case in an inter-case matrix. Second, reasons for non-adoption of IES are addressed. Third, the results of the QCA are presented. Finally, the results of the confirmatory analysis with bivariate correlations are presented thereafter. To start the overview of the results, a geographic map of The Netherlands is presented in Fig. 14.2, showing the locations of the sites studied.

14.6.1 Case Characteristics

The important characteristics are summarized per case in Table 14.1. The data include the number of houses renovated, the type of house, and the estimated energy conservation achieved (as a percentage). It also presents information on innovative energy systems that were part of the planning stage of projects and actual application in the realization stage of the project. Table 14.1 is structured in descending sequence according to the category 'estimated degree of energy conservation'.

The site with the smallest amount of energy conservation achieved had a value of 26.5% (Atol-en Zuiderzeewijk), while the site with the largest amount of energy conservation achieved had a value of 69.8% (Groot Kroeven). In the latter case the

Fig. 14.2 Images of locations of cases studied in the Netherlands

innovative concept of passive renovation (the renovation variant of passive housing[1]) had been applied, a technology that features extreme insulation standards and the use of passive solar energy. Besides the Groot Kroeven case IES were only successfully applied two other cases: Europarei and Hogewey.

[1] 'Passive housing' is an integral concept that combines several measures that improve energy efficiency of houses. It combines high quality insulation, mechanic ventilation with heat re-capture, orientation towards the sun. Sometimes, solar heating and solar PV systems are installed in addition. The standards are high: the limit is 15 kWh/m^2 floorspace annually.

Table 14.1 Key characteristics in cases

#	Name of site	Name of town	Number of dwellings	Dwelling type	Estimated degree of energy conservation (%)	IES (ambition)	IES (actually implemented)
1	Groot Kroeven	Roosendaal	246	Family house 1960s	69.8	Several options considered	Passive housing standards applied
2	Eygelshoven	Kerkrade	300	Family house 1950s	51.1	Several options considered	None
3	Europarei	Uithoorn	635	Apartment 1960s	50.2	Solar heating	Solar heating and air heat pump
4	Prinsenhof	Leidschendam-Voorburg	1,628	Apartment 1960s	43.8	Several options considered	None
5	Hogewey	Weesp	258	Apartment 1960s	35.0	Several options considered including heat pumps/ geothermal	Fleece wall and decentral cogeneration
6	Espels	Leeuwarden	117	Family house pre-War	34	None	None
7	Binnenstad-Oost	Helmond	121	Family house pre-War	32.9	None	None
8	Tannhäuser	Apeldoorn	100	Apartment 1960s	32.9	City heating from biomass plant	None
9	Bijvank het Lang	Enschede	854	Family house 1970s	30.5	City heating for heating water	None
10	Nieuwstad	Culemborg	200	Family house 1970s	30.1	Several options considered	None
11	Atol- en Zuiderzeewijk	Lelystad	380	Family house 1960s	26.5	None	None

14.6.2 Reasons for Not Applying IES

In 8 out of 11 cases IES were not applied. In five of those cases IES were originally planned but the application failed to make it through to the installation phase. Table 14.2 summarizes the reasons for non-application of innovative energy systems. IES in the successful cases, originally planned but not implemented, are also addressed. Although a list of reasons for non-implementation is given, there is no similar list for implementation. The analysis of successful implementation involves QCA and is addressed in the next section.

14.6.3 Results of the Empirical Analysis of the Application of IES

Qualitative comparative analyses of the different variable clusters were conducted to identify the causal drivers behind the phenomenon that IES were applied.

Results on the cluster 'instruments of climate policy'

Two conditions were identified as necessary but not sufficient in case IES were applied: subsidies and communicative policy instruments. Case histories provide the insight that IES might also be applied without subsidies, but only after IES had previously been applied successfully after subsidies had been used. Positive experiences from subsidized projects taught that housing associations learned to perceive and appreciate the benefits of IES, in such a way that application without subsidy became feasible. Moreover, subsidies were necessary as stepping stones, but after experience was gained, housing associations dared to invest the total amount themselves and subsidies were no longer necessary. A sufficient degree of information was also necessary, as demonstrated by energy audits and information from national government. Covenants had little impact, although they clearly had beneficial supportive functions in some cases.

Results on the cluster 'organizational characteristics of the housing association'

Two necessary but not sufficient conditions were found in case IES were applied: the presence of 'advocates' and staff specialized in energy affairs. In all three cases in which IES were applied, a highly motivated, influential project manager was in charge of operations in the renovation projects. In addition, combinations of conditions were identified that preceded the application of IES. Most include alignment between departments, financial reserves and formal energy policy. Alignment between departments within the housing association and formal policy that were involved when IES were not applied, however. Further investigation led to an explanation stemming from recent reorganizations, mergers, and the increasing scale of the housing associations.

Table 14.2 Reasons for not applying IES

Reason for non-application of IES	Frequency and case(s)
The establishment of a biomass plant near the project location was cancelled. As the whole plan was based on connecting pipelines from the plant (city heating) to the housing block, failure was assured when plans to construct the biomass plant were put on hold when a permit was not granted.	1 (Tannhäuser)
A lack of trust occurred between the local authority and the housing association leading to the loss of 'renewable energy' as an item on the project agenda.	1 (Nieuwstad)
Tenants did not favour the maintenance of a collective heating system. They were afraid that the energy costs were not to be divided proportionally. This led to a decision in favour of individual heating systems, which were unsuitable for IES application.	2 (Prinsenhof, Hoegewey)
Advice deriving from the energy audit was never seriously taken into account. The advice was regarded as symbolic only.	2 (Eygelshoven, Binnenstad-Oost)
Tenants feared an increase in their monthly rents which was a reason for their housing association to renounce any options to apply renewable energy systems. Moreover, the housing association did not want to make any uneconomic investments.	1 (Bijvank het Lang)
The renovation project had been delayed in the initiation stage, and the tenants were tired of waiting. Speeding up the project did not leave any room for the procedure to get the legal permit to use ground water in order to apply heat pumps for geothermal energy.	1 (Hogewey)
The application of innovative energy systems was never a serious consideration for the project planners. The ambition was never better than the conventional measures being applied. The housing association also did not have the financial means to make such an investment.	2 (Atol- en Zuiderzeewijk)
A bad experience with the application of an energy efficient system in a previous project led to a 'deadlock' concerning application of similar systems. Concerns regarding poor financial feasibility were the main reason.	1 (Prinsenhof)
The application of a biomass-fired energy generation plant in residential areas was not considered a feasible option by decisionmakers.	2 (Hogewey, Groot Kroeven)

Results on the cluster 'organizational characteristics of the local government'

Three necessary but not sufficient conditions were found for non-application of IES: specialized staff in energy affairs, fine-tuning between departments within the local government, and intergovernmental policy support (the so-called 'BANS' scheme). These conditions also correlate strongly between themselves. Strikingly, the intergovernmental scheme – designed to encourage the design and implementation of local climate policy – rather hinders than encourages the application of IES in existing residential areas. Further investigation in the case histories teaches that IES are considered feasible in sites with newly constructed houses, but not so much in existing areas. In this context many other predominantly social project goals are afforded greater weight. Secondly, there is an easier and quicker return on investments from developing and selling new houses than renovating existing ones, which are perceived as unprofitable. Moreover, IES were successfully applied in renovation projects in small-sized municipalities in which the local authorities showed little ambition for the implementation of local climate policies. This result may be perceived against the background of complex institutional problems that go hand in hand with neighbourhood revitalization projects in post-War urban areas (for further elaboration see Hoppe and Lulofs 2011).

Results on the cluster 'inter-organizational collaboration'

Two necessary but not sufficient conditions were identified in case IES were applied: presence of 'opinion leaders' and frequent visits to thematic meetings. These meetings concern recent developments in renewable energy technologies and energy-efficient systems, and involve both experts and practitioners. In our cases they were organized by national, regional governments or NGOs, and enabled 'cross-fertilization' of innovative ideas and experiences. Without the combination of the presence of a highly motivated, authoritative person close to the decision making organ (the opinion leader), and frequent visits to thematic meetings, important information is not diffused, which is critical to the application of IES.

Results on the cluster 'cognitive cohesion'

No necessary or sufficient conditions were found in this cluster. Only a combination of the conditions concerning (high) environmental orientation and (high) adoption of technical innovations orientation preceded successful application of IES.

Results on the cluster 'contextual factors'

Two necessary conditions were identified. In the first place, policy support from urban renewal policy disabled successful implementation of IES. IES were not implemented in locations where local or even national government had any influence on the locus of urban renewal policies. On the contrary: locations where IES were successfully applied were all similar in their lack of large neighbourhood revitalization plans, with a concomitant lack of government influence, which meant that housing associations exercised greater independence.

Second, relatively large investments per house renovation facilitated the application of IES. This can be interpreted as a 'sunk costs' argument. When the opportunity occurs, additional IES measures can be taken to improve the house. Because a large investment is being made anyway, the burden of the additional measure is relatively light. By contrast, lengthening the term of exploitation – a measure that is often mentioned to make investments profitable – does not influence the more widespread application of IES.

It is striking that tenant participation could not be identified as a necessary condition. For example, in the Prinsenhof case tenants were asked to vote whether to maintain the collective heating system or not. In multi-story buildings maintenance of the collective heating system is a precondition for applying IES, and is even cheaper than the alternative of individual heating systems. Although the housing associations presented information that actually demonstrated the significant financial benefits of the collective systems (€10 per month), the tenants outvoted the alternative of maintaining the collective system. Furthermore, several combinations of causal, context-related items were found that militated against the installation of IES: address density, a (large) number of houses on-site, and the (large) share of newly built houses on-site.

14.6.4 Confirmatory Analysis with Bivariate Correlations

The results from the qualitative comparative analysis were investigated by computing bivariate correlations in order to confirm or disconfirm the results. Because QCA does not allow for scaling techniques, the separate underlying items of the variables in the box were analysed. The results of the analysis are presented in Table 14.3.

The results of the confirmatory analysis are presented in Table 14.4. Except for one item, all results from the QCAs were confirmed.

14.6.5 Interpretation of the Results

No condition was found that was both necessary and sufficient. Interpretation of the analysis of non-application of IES provides two further results of interest. Some statements need to be made when addressing the clusters of variables. First, the clusters 'instruments of climate policy', 'organizational characteristics of the housing association' and 'inter-organizational collaboration' contained significant items that correlate positively with the application of IES. This is in conformity with our expectations. The cluster 'characteristics of the local authority' did have significant items, but contrary to the directions we hypothesized. These results are surprising, and may disprove the interpretation of the degree to which local authorities exercise an influence over the local application of IES in renovation projects in existing residential areas. We did not identify significant items in the cluster 'cognitive cohesion'. However, a combination was found that positively correlates with the application of IES. Finally, the cluster on contextual factors had two significant items, one in the positive and one in the negative direction.

In summary, IES were not applied in the absence of a sufficient degree of collaboration, in the absence of a sufficient number of policy instruments, in the absence of energy efficiency advocates and sufficient personnel capacity at the housing association, and when positive organizational characteristics towards energy efficiency of local governments were present. The latter is in contrast to our expectations. One might expect that government organizations with plenty of staff, formalized energy policy plans, and intergovernmental budgets for local climate policy would be more likely to have IES installed, but our results do not confirm these views. Necessarily, this finding needs further elaboration.

Table 14.3 Bivariate correlations

Indicator name	r	p
Cluster 'policy instruments from the domain of climate policy'.		
Use of communicative policy instruments	.465	.075
Presence of local or regional covenants	−.056	.435
Use of subsidies	.759	.003**
Cluster 'organizational characteristics of the local government'.		
Financial support by national government (BANS)	−.639	.017*
Political orientation of the officials	−.227	.251
Orientation to the environment	−.562	.036*
Membership of climate treaty	−.542	.043*
Size of the municipality	−.477	.069
Organizational fine-tuning	−.659	.014*
Personnel capacity	−.412	.104
Formal climate policy	−.304	.182
Presence of energy efficiency advocates	−.116	.367
Cluster 'organizational characteristics of the housing association'.		
Financial position	−.083	.404
Organizational fine-tuning	−.088	.399
Number of houses in property (size of stock)	−.303	.182
Formal climate policy	−.194	.284
Presence of energy efficiency advocates	.717	.006**
Orientation towards the environment	.132	.350
Personnel capacity	.453	.081
Cluster 'inter-organizational collaboration'.		
Frequency of visits to thematic meetings	.597	.026*
Size of the project configuration over time	.473	.071
Opinion leadership	.607	.024*
Cluster 'cognitive cohesion'.		
Cohesion towards the national climate policy strategy	.076	.422
Cohesion towards environment and sustainable development	−.309	.178
Cohesion towards technological innovation adoption	.155	.325
Cluster 'project context'		
Exploitation term lengthening of renovated houses	.016	.481
Distance to district heating facility	−.218	.259
Support by urban renewal policies	−.761	.003**
Number of houses	−.086	.401
Equilibrium in public housing market	−.403	.109
Institutionalization of energy efficiency in decision-making process	−.231	.247
Initial energy quality of houses	.286	.197
Degree of public participation	.364	.136
Type of heating system	.256	.224
Distribution of property ownership	.348	.147
Address density	−.225	.253
Share of newly built houses	−.341	.152
Investment per house	.754	.004**

* significant at .05 level
** significant at .01 level

Table 14.4 Results of confirmatory analysis between QCA and correlational analysis (plus direction regarding the correlation)

Variable cluster	Items identified csQCA as necessary conditions	Confirmatory analysis
Instruments of climate policy	Subsidies (+)	Confirmed
	Communicative instruments (+)	Confirmed
Organizational characteristics of the housing association	Advocate for energy efficiency (+)	Confirmed
	Staff specialized in energy affairs (+)	Confirmed
Organizational characteristics of the local authority	Intergovernmental scheme BANS (−)	Confirmed
	Internal alignment between departments (−)	Confirmed
	Staff specialized in energy affairs (−)	Not confirmed
Inter-organizational collaboration	Opinion leadership (+)	Confirmed
	Frequent visit of thematic meetings (+)	Confirmed
Cognitive cohesion	None	–
Contextual factors	High investment per house (+)	Confirmed
	Urban renewal policy support (−)	Confirmed

14.7 Conclusion

In this chapter we have tried to answer the question of which factors explain the application of innovative energy systems in renovation projects in residential areas. This issue is quite important as the diffusion and deployment of clean technologies in large energy consuming sectors is important to reduce substantial GHG emissions and therefore contributes to achieving green growth. In our study we sought six theoretical explanations: the influence exercised by policy instruments, the influence exercised by housing associations, the influence exercised by local governments, collaborative efforts between actors, cognitive cohesion between actors, and contextual factors.

Policy instruments were found to be of prime importance to the appliance of innovative energy systems. Subsidies and communicative policy instruments were necessary but not sufficient conditions. Covenants were neither necessary nor sufficient. Rather, they arose out of previous projects and local experiments. The analysis showed that *housing associations* were primarily involved with social issues (their prime business). When the application of IES was at stake the executive board demanded that external finance, such as subsidies, be acquired. The privatization, starting in 1995, might be the reason why the housing associations discount every investment harshly. However, this trait can be combined with the application of IES if two conditions are met: there has to be a highly motivated and influential project manager, and there has to be a staff specialized in energy affairs. Although the adoption of corporate social responsibility standards among housing associations is rising, the application of IES can be considered more a personal motivation by individual managers within housing associations than one that derives from the executive board following a formal policy document or CSR statement. Furthermore, in our cases IES were only installed when relatively small-sized housing associations were involved. This might be an indication that larger ones have too many other concerns to worry about, given the size of their organization and the housing stocks they manage. The role of *local governments* was rather limited, as they only exerted an influence in the planning stages of projects or played minor, supportive roles. Strikingly, the successful projects were all located in relatively small municipalities within which lay only local governments with small staffs that likewise lacked the capacity to pay much attention to local climate policy, including the installation of IES in residential areas. *Tenants* turned out to be little concerned with the energy efficiency of their homes. In some cases they actively preferred conventional, suboptimal systems over more energy-efficient alternatives, even though additional information was provided on direct financial benefits. The reason for this lies in a fear of increased direct energy costs, unequally divided costs among tenants in the building block, and distrust of the housing association's plans. With regard to *inter-organizational collaboration* it can be stated that without the presence of a highly motivated, authoritative person close to the decision making (the opinion leader), combined with frequent visits to thematic meetings, important information is not diffused, which is critical to the application of IES. Two *contextual factors* were important: a large total investment per dwelling, and policy support for urban renewal activity. The latter exerts a negative impact, indicating that urban areas troubled by a plethora of social problems do not provide optimum conditions for meeting environmental goals such as the application of IES.

In sum, three variables exercised a rather positive influence on the application of IES: policy instruments (climate policy), housing associations' organizational characteristics (but only in terms of energy efficiency advocates and personnel specialized in energy affairs), and inter-organizational collaboration.

Although innovative renewable energy and energy efficiency technologies offer great opportunities to improve energy performance in houses in residential areas (and hence decrease GHG emissions), our research results can be perceived as highly sceptical of the deployment of such technologies in the housing sector in the Netherlands. There appears to be a great divide between ambition setting and goal achievement at the local level. Apparently, the goals set are too ambitious and the current policy mix is inadequate to gain commitment from key actors. Harvesting the technical potential of energy efficiency is far from being an accomplished goal. Future research and policymaking should devote careful attention to the way local actors should be addressed in order to gain commitment (from both households and housing associations), and to see how local authorities may actively facilitate the project of furthering energy efficiency in housing renovation sites, and not just by setting ambitious goals. Furthermore, systematic, in-depth comparison of local level projects, as well as international comparative analyses are necessary to assist the Dutch national government, the European Union and the OECD to develop strategies that encourage the 'greening' and better energy performance of domestic housing in current residential areas.

It is up to them to provide policy incentives that foster the further deployment of clean energy technologies in the domestic housing sector. This is important since the greening of energy usage is a significant element of green growth.

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Chapter 15
Why Consumers Buy Green

Nicole Darnall, Cerys Ponting, and Diego A. Vazquez-Brust

Abstract Increasingly, consumers are becoming more knowledgeable about the environment and reflecting this knowledge in their decisions to buy green products. While previous research on the topic has generally examined green consumption related to a single product label, numerous questions exist about why consumers choose various green products and services. We address these concerns by examining individuals' actual green consumption as it relates to their trust of various sources to provide them with environmental information, environmental knowledge, and personal affect towards the environment. These relationships are studied for a sample of more than 1,200 UK residents using multiple regression techniques. We show that individuals' total green consumption is related to their trust of various sources to provide them with environmental information, environmental knowledge, and personal affect towards the environment. These findings have important implications to policy-makers and businesses alike as greater efforts are made to encourage more widespread green consumption.

Keywords Green purchasing • Green consumerism • Green consumption • Trust • Environmental knowledge • Eco-label

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15.1 Introduction

Individuals worldwide are becoming increasingly savvy about the environment, and basing their purchasing decisions on a product's environmental attributes (Darnall 2008; Perrini et al. 2009). For instance, within the United States (US), approximately 15% of consumers routinely pay more for green products, and another 15% seek green products if they do not cost more (Ginsberg and Bloom 2004). Similarly, consumers in Costa Rica are willing to pay price premiums of $30 per night for hotel services that have certain eco-labels (Rivera 2002). Consumers have also revealed a willingness to spend 20–50% more for organically labelled food (Barkley 2005). In spite of their greater cost differentials, by the end of 2007 international sales of UK organic products climbed to €33.7 billion, which represents a 10% increase from the prior year (Perrini et al. 2009). As a consequence, there is a compelling reason for governments and companies to understand more about why consumers buy green.

Previous research on the topic has generally examined green consumption related to a single product label. In particular, earlier scholarship has considered consumer purchasing decisions related to organic certified products (Perrini et al. 2009; Loureiro et al. 2001), eco-labelled food (Loureiro et al. 2001), sustainable forest products (Teisl et al. 2002) and energy labelled electrical appliances (Sammer and Wüstenhagen 2006; Mills and Schleich 2009). These studies illustrate that there are numerous types of labels that might influence consumers' shopping decisions. However, as yet researchers have little sense regarding factors that are related to consumers' *overall* green consumption (Galarraga-Gallastegui 2002).

Of the existing studies that have examined aspects of consumers' green consumption, prior scholarship has emphasized environmental knowledge and attitudes as important correlates (Schlegelmilch et al. 1996). Other studies have focused on the socio-demographic aspects of consumers who buy green, albeit with mixed findings (Straughan and Roberts 1999; McDonald and Oates 2006). However, information is lacking regarding how different sources of environmental information may influence these decisions (McDonald and Oates 2006; Schlegelmilch et al. 1996), especially as it relates to consumer trust of these information sources. Moreover, much of the existing research is based on weak empirical examinations (Sammer and Wüstenhagen 2006), small samples or restricted geographic scopes. As such, we have had limited ability to generalize the findings. This issue is particularly important since many more companies now market their products to other countries, and as such a more robust international examination is needed (Lee 2008).

Understanding why consumers buy green is increasingly important to policymakers. While market failures related to pollution can be addressed by regulating firms through coercive measures, coercive regulations have been limited within consumer markets (outside of product bans or taxes to curb consumer demand). However, government-sponsored eco-labels are one example of a regulatory tool that is being used with increasing popularity. Even if only a small portion of consumers uses the environmental information in making their product purchases, a small portion is all that is needed to encourage the broader population of firms to radically change their production decisions in an environmentally friendly way (Moorman 1998). Moreover, if a majority of consumers shift towards making green purchases, it is possible that *most firms* will make a switch towards green production (Eriksson 2008). The societal benefits of this arrangement would be profound and largely infeasible using coercive regulations on their own (Eriksson 2008). However, for government to encourage more widespread green consumption, policy makers must know what factors encourage consumers to buy green. This is especially true for consumers who are at the margin in that they presently do not buy green but may if presented with the right circumstances.

We address these concerns by examining individuals' green consumption as it relates to their trust of environmental information sources, environmental knowledge, and personal affect towards the environment. These relationships are studied for a sample of more than 1,200 residents living in England, Wales, and Scotland using multiple regression estimation techniques that control for numerous confounding concerns.

15.2 Understanding Green Consumerism

Green consumption is the purchasing and non-purchasing decisions made by consumers, based at least partly on environmental criteria (Peattie 1995). In general, green consumption stems from individuals' idealism to internalize some of the negative externalities from the production of the green goods they buy (Eriksson 2008).

Green consumerism has roots in the 1970s when public concern for the environment became mainstream (Vazquez and Liston-Heyes 2008), as did the notion that government should take the lead in mitigating specific environmental problems. However, in the late 1980s and early 1990s, a new 'green thinking' emerged (Dryzek 1997). Green thinking advocates argued that most environmental problems were borne from the prevailing socio-economic systems of production and consumption. Remedying environmental problems therefore required a broader emphasis on changing these socio-economic systems (Dryzek 1997) rather than simply focusing on government policies that address a media-specific environmental problem. Fueling this individual-focused consciousness were popular publications, such as *The Green Consumer Guide* (Elkington and Hailes 1988), which laid the foundation for debates about eco-labelling in Europe, and encouraged a greater emphasis on green consumerism during the 1990s (Jordan et al. 2004).

Green consumerism often is viewed as a business opportunity. Customer surveys show that about 44% of customers report their willingness to pay a premium price for green products (Chattaway 2008). For instance, consumers have revealed a willingness to spend 20–50% more for hotel services (Rivera 2002) and organically labelled food (Barkley 2005). In the decade from 1985 to 1995 the percentage of green products as a percentage of total new products increased from 0.5% to 9.2% (Min and Galle 1997). These increases are holding strong in that by the end of 2007 international sales of UK organic products were increasing at a rate of 10% increase per year (Perrini et al. 2009). At the same time, more firms have been developing products and marketing strategies aimed at the green thinking consumer (Peattie 1992). For firms that are committed to developing these products, they can also benefit by enhancing their social legitimacy. They can also improve their intangible value related to developing an eco-friendly reputation, enhance their relations with environmental regulators, and bolster their community standing (Darnall 2008). Together, these activities can improve a company's long-term survival and competitiveness.

While customer surveys have reported increasing levels of consumer awareness for environmental concerns (Peattie and Crane 2005), reliable information about corporate environmental activities is limited, which hinders consumers from buying green. Customer scepticism of firms' green production and product claims has also been increasing (Peattie and Crane 2005; Harris 2007; Bamberg and Moser 2006; Thøgersen 2000; Grankvist et al. 2007; Moisander 2007).[1] The distrust is warranted. For instance, within the US during the early 1990s, approximately half of the environmental advertising has been considered misleading or deceptive (Kangun et al. 1991). The amount of deceptive environmental advertising is expected to be greater today given society's burgeoning interest in environmental issues and the proliferation of unverifiable environmental information. This concern has led the US Federal Trade Commission (FTC) to fast-track review of its 1998 regulations on green marketing. The FTC sees the largely unregulated area of "green advertising" as a primary target for consumer deception (Bastile and Skierka 2008).

These concerns suggest that while green consumption and the green thinking movement may be viable pathways towards achieving widespread environmental improvements, they may need to be accompanied by a variety complementary efforts, such as enhancing government incentives for both green consumption (Autio et al. 2009; Darnall 2008) and production (Eriksson 2008; Darnall 2008), and stronger regulatory oversight regarding advertising claims. To address this latter concern, in the early 2000s the EU initiated an information campaign to guide customers in the acquisition of low-energy consumption products (Rex and Baumann 2007). In the UK, government education efforts occurred due to pressure from a variety of groups (e.g., Friends for the Earth and the National Consumer Council) that were expressing greater concern about the greater need to address

[1] Scepticism does not necessarily stem from false claims. Peattie and Crane (2005) identified 5 main bad marketing practices leasing to customers distrust: PR used to discredit environmental criticisms; adding green claims to existing products to increase sales; being eco-friendly only when it leads to cost savings; creating new green products that are not wanted by customers and claiming green credentials while not doing more than complying with existing regulation.

climate change (Young et al. 2010). Additionally, governments and non-government organizations (NGOs) worldwide are taking a more prominent role in terms of regulation and standardization of corporate claims (Rex and Baumann 2007). However, as yet, we know little about the reasons why consumers buy green across a variety of products and services.

15.3 Predicting Green Consumption

There are numerous examples of green consumerism, we examine an individuals' total green consumption. To adequately understand an individual's total green consumerism, each consumer's behaviour must be viewed as a series of purchase decisions (Peattie 1999). These decisions may be inter-related and underpinned by common values or they may be unconnected and situational (Peattie 1999). There are no agreed criteria for what is green consumption or a green product (Young et al. 2010). However, prior studies and general logic serve as a guide. In general, green products include choosing organic meat, organic dairy products (milk/cheese/yoghurt), organic vegetables (Beckmann 2001), fair trade products (Galarraga-Gallastegui and Markandya 2000). Additionally, green purchasing decisions can involve buying locally grown food or products that were produced locally, choosing unpacked fruit and vegetables, and avoiding buying food that is not in season. Related to household products, green consumption includes purchasing, recycled toilet paper, energy efficient light bulbs (Defra 2002), natural cleaning products, recycled stationery, sustainable clothing (i.e., organic cotton or hemp). It also might involve purchasing more durable products that optimize energy efficiency of electrical products and appliances. Together, these examples illustrate the numerous purchasing and non-purchasing decisions that comprise an individual's total green consumption.

In considering the factors related green consumption, we consider consumers' trust of sources to provide information about environmental concerns, and consumers' environmental knowledge and personal affect towards the environment. Each is discussed further below.

15.3.1 Trust of Sources Provide Information About Environmental Concerns

Trust is defined as an individual's intention to accept vulnerability based upon positive expectations of the intentions of the behaviour of another (Rousseau et al. 1998) individual or entity. Trust allows for risk-taking in a relationship (Mayer et al. 1995), and is needed especially where other control systems (Schoorman et al. 2007) or regulations are lacking. In this context, trust is especially relevant, as regulatory oversight governing informational claims is generally weak (Bastile and Skierka 2008). However, as yet, little is known about how different environmental information sources may influence consumer decisions (McDonald and Oates 2006; Schlegelmilch et al. 1996), especially as it relates to consumer trust of these sources.[2] We anticipate that consumers will respond differently to environmental information sources based on the trust they have of those sources.

Among other sources, consumers receive environmental information from government, environmental NGOs, scientists, and personal connections with friends and family. In considering government as a source of environmental information, it is the primary entity responsible for protecting the global environmental commons, establishing environmental laws, and seeing that the environment is protected. Government is also tasked with protecting customers from false market claims, establishing guidelines for product labels and acceptable marketing claims, and for undertaking legal action against companies that fail to comply with established guidelines (Rex and Baumann 2007). Outside of coercive regulations and enforcement, government has taken a lead role in creating eco-labels and providing consumers with environmental information about the merits of environmental labels and green consumption in general. Some scholars have suggested that government sponsorship and oversight of eco-labels has increased their consumer appeal (Ottman et al. 2006; Harris 2007). For these reasons, we posit that consumers who trust the environmental information put forward by government are more likely to buy green.

Like government, environmental NGOs help protect customers from false market claims by developing eco-labels and eco-label guidelines (Rex and Baumann 2007). Environmental NGOs also are more likely to protest publicly against labels that fall short of environmental expectations (Rivera and de Leon 2004), and this scrutinizing role has also increased consumers' overall appeal towards green products (Ottman et al. 2006; Harris 2007). It also has increased the legitimacy of eco-labels that are sponsored by environmental NGOs (Banerjee and Solomon 2003; Knott et al. 2008; Scammon and Mayer 1993, 1995). As a consequence, consumers who trust the environmental information put forward by environmental NGOs are anticipated to be more likely to buy green.

Scientists are one of society's primary sources of environmental information. They are the originators of independent studies that speak to the condition of the environment and to global climate change. For instance, the Intergovernmental Panel on Climate Change has released four highly publicized reports on global climate change and received the 2007 Nobel Peace Prize for its efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change

[2] While environmental consciousness can impact consumers' purchasing decisions, questions remain about how sources of information play a role (Schlegelmilch et al. 1996). Information sources are particularly relevant in that while a growing number of consumers may be aware of the environmental impacts of their shopping choices, and showing interest in understanding how to choose more environmentally friendly items (Maciag and Hepting 2008), many customers still find difficult to buy green products. It is believed, however, that these same consumers may be more likely to purchase environmentally friendly products if trusted information sources were available (Young et al. 2010; Knott et al. 2008).

(IPCC 2010). Because of their credentials, scientists can have a significant impact on societal perceptions. For these reasons, we anticipate that consumers who trust the environmental information put forward by scientists are more likely to buy green.

Friends and relatives are the most trusted individuals in our social networks. To the extent that these individuals possess environmental information, they can have significant bearing on consumers' decisions to buy green. Indeed, friends and family are reported as the most trusted sources of purchasing information source for buying green (Oates et al. 2008; Lee 2008; Young et al. 2010). For these reasons, we posit that consumers with greater trust of government, environmental nonprofits, and friends/family, and scientists to provide environmental concerns information are more likely to buy green.

Hypothesis 1: *Consumers with greater trust of government, environmental nonprofits, and friends/family, and scientists to provide environmental concerns information are more likely to buy green.*

Private business is also a source of environmental information. However, environmentally conscious customers often report ignoring green advertising claims (Oates et al. 2008) or feeling confused about the environmental claims used by firms (Mayer et al. 1993). These consumers report their distrust of firms' own eco-labels because they 'did not tell the whole story' (Oates et al. 2008), made false claims (Banerjee and Solomon 2003), exaggerated messages, or lacked clear meaning (Fay 1992; Carlson et al. 1993; Scammon and Mayer 1995). Corporate messages such as these are referred to as "greenwashing," or the practice of companies disingenuously presenting their products and policies as being environmentally friendly.

The root of corporate greenwashing rests in whether profit-seeking organizations have sufficient market incentives to voluntarily incur additional private costs to protect the environment (Darnall et al. 2010). In the absence of sufficient incentives, private business may symbolically change their products to create the public perception that they are green, rather than radically changing their production processes to create truly green products. In so doing, corporate greenwashers can derive an economic benefit by producing false claims about the greenness of their products. Such actions increase consumer distrust of *all* green products, reduces consumers' willingness to buy green (Peattie and Crane 2005), and creates barriers toward encouraging broader societal change (Knott et al. 2008). For these reasons, it is our belief that individuals who distrust private firms' environmental information do not pay attention to corporate marketing claims.

Hypothesis 2: *Consumers with greater distrust of private business to provide environmental concerns information are no more likely to buy green.*

15.3.2 Role of Environmental Knowledge

Prior research examining the factors related to green purchasing assert that an individual's ecological behaviour is highly dependent upon his/her knowledge of the relevant environmental issues (Young et al. 2010; Chan 2001; Moisander 2007; Oates et al. 2008; Bamberg and Moser 2006). The broader literature reports a positive relationship between knowledge and behaviour (e.g., Hoch and Deighton 1989; Park et al. 1994). However, related to environmental research, this relationship is not as consistent (Martin and Simintiras 1995). For instance, Chan (2001) notes that some studies have found a positive association between ecological knowledge and environmentally responsible behaviour (Dispoto 1977; Kilkeary 1975; Hines et al. 1986/87), while others have shown that no significant relationship (Arbuthnot and Lingg 1975; Geller 1981; Schahn and Holzer 1990). Such mixed empirical findings may suggest a more complex relationship between ecological knowledge and behaviour (Chan 2001).[3]

Consumers' environmental knowledge influences their behaviour in several different ways. First, knowledge serves as a personal resource to make decisions and as a driver of personal responsibility (Moisander 2007). Additionally, knowledge influences what individuals view is within their behavioural control (Bamberg and Moser 2006). It affects both motivation and ability to act in an environmentally friendly way (Bamberg and Moser 2006; Moisander 2007). For these reasons, we posit that individuals who have knowledge of critical environmental issues are more likely to buy green. In particular, we consider two types of environmental knowledge—general knowledge and action based knowledge.

General knowledge relates to consumers' rudimentary understanding of environmental issues. It involves a general awareness of basic terminology and concepts. Consumers lacking general knowledge find it more difficult to understand environmental information whereas more knowledgeable consumers can more readily digest a wide range of environmental information. Environmentally knowledgeable consumers therefore can make more rapid decisions that translate into action (Moisander 2007).

By contrast, action-based knowledge relates to consumers' understanding of the activities required to *mitigate* environmental problems. It includes an awareness of consequences of individuals' actions on the environment and awareness of the remedies that can improve behaviour (Hines et al. 1987) Action-based knowledge is not only a personal resource, but it also influences consumers' sense of personal responsibility for green behaviours. That is, if a person is aware of the consequences of their behaviour, an ascription of personal responsibility typically follows. For these reasons we hypothesize that consumers with greater general and action-based knowledge related to environmental concerns are more likely to buy green.

Hypothesis 3: *Consumers with greater general and action-based knowledge related to environmental concerns are more likely to buy green.*

[3] A general criticism of this work is that it is based on relatively unsophisticated empirical examinations, small samples (Sammer and Wüstenhagen 2006) or limited geographic scopes. As such, they are limited in their ability to offer generalizable findings. Generalizability of the results is particularly important since many more companies now market their products to other countries, and as such a more robust examination across multiple boundaries is needed (Lee 2008).

15.3.3 Personal Affect Towards the Environment

Other factors associated with why consumers buy green relate to consumers' personal affect towards critical environmental issues. A consumer's personal affect refers to the emotional state elicited from a particular issue. Related to the environment, personal affect relates to a consumer's emotional state related to environmental concerns.[4] We suggest that a consumer's sense of personal risk and empowerment to address critical environmental problems are particularly salient personal affects related to green consumption.

Sense of personal risk relates to the perceived individual harm that may arise from a future environmental event. Individuals who feel that there is a personal risk related to the environmental problems are more likely to be aware of the consequences of their individual behaviours (Vining and Ebreo 2002). These relationships have been examined in other environmental applications, and show that they predict pro-environmental behaviours related to recycling (Hopper and Nielsen 1991; Vining and Ebreo 1991, 1992), household energy saving (Black et al. 1985) and reduced private car use (Bamberg and Schmidt 2003). We believe that they also relate to consumers' decisions to buy green.

Sense of empowerment refers to whether or not an individual is confident that his/her personal actions have bearing on a critical environmental issue. Individuals with a higher sense of behavioural control tend see change as something they can actively manage whereas individuals who have a low sense of behavioural control see it as somehow random or reserved for more influential people (Fransson and Garling 1999). Related to the natural environment, individuals who have a stronger sense of empowerment towards environmental concerns may be more likely act to mitigate those concerns. For these reasons we hypothesize that consumers with greater personal affect related to environmental concerns are more likely to buy green.

Hypothesis 4: *Consumers with greater personal affect related to environmental concerns are more likely to buy green.*

15.4 Methods

To evaluate our hypotheses, we relied on data collected from an online survey that was co-developed and administered by the Centre for Business Relationships, Accountability, Sustainability and Society (BRASS) at Cardiff University and

[4] Related scholarship has considered how moral responsibility applies to environmental behavior, especially in terms of whether a person feels they cause the problem (Kaiser and Shimoda 1999). This research suggests that 55% of a person's ecological behavior can be explained by what they term, a responsibility judgment (Kaiser and Shimoda 1999). However, personal affect differs from responsibility in that the latter implies a perceived moral commitment or expectation to address the concern, whereas the former refers to a more general state of concern in the absence of obligation.

The Future Foundation, a consumer insight and strategic futures company. The survey asked UK consumers about their consumption behaviour, perceptions about climate change, and trust of different societal sources.

At the time of the survey, approximately 60 million individuals live within the UK. The sample was limited to consumers who had internet access. These consumers accounted for 63% of the population (approximately 38 million residents). *Research Now*, a nationally recognized UK market research firm, was enlisted to help finalize the sample. To ensure that the sample was representative, Research Now stratified UK residents by gender, age, household income, terminal education age, region, postcode, car ownership, and household tenure, personal income, working status, number of adults in the household and number of children. The resulting sample consisted of approximately 400,000 UK consumers, who were then randomly sampled.

In September 2007, a total of 1,513 consumers were surveyed online. Prior to its finalization, the survey was vetted among several leading scholars in the field of green consumerism. *Research Now* offered respondents a financial incentive for the completion of the surveys, which ensured a relatively high response rate. A total of 1,278 (84.5%) individuals within the sample completed the survey in its entirety.

To check for common method variance, we relied on the post-hoc Harman's single-factor test (Podsakoff and Organ 1986). This test assumes that if a substantial amount of common method variance is present, a factor analysis of all the data will result in a single factor accounting for the majority of the covariance in the independent and dependent variables. The results of Harman's single-factor test revealed that no single factor accounted for the majority of the variance in the variables, offering evidence that this type bias was not a concern.

Social desirability bias was addressed by ensuring respondent anonymity. Anonymity assurances reduce bias even when responses relate to sensitive business topics. To further address potential problems related to social desirability bias, survey questions related to consumers' green purchasing behaviour were separated from questions pertaining to environmental perceptions and education, in addition to questions related to institutional trust. In instances where a social desirability bias exists, researchers are less likely to identify statistically significant relationships because there is less variability in respondents' survey answers. However, by finding statistical significance, additional evidence would be offered about the strength of the relationship between the variables of interest (Hardin and Hilbe 2001). Non-response bias was less of a concern because of the survey's high response rate.

15.4.1 Measures

15.4.1.1 Dependent Variable

For the purposes of this study, *total green consumption* accounted for the extent of consumers' overall green consumption related to food and household products. More specifically, consumers were asked "Which of the following do you do nowadays

Table 15.1 Government trust factor analysis[a]

Government trust to provide climate change information—"How much do you trust the following entities to provide you with information on climate change . . ."	**Factor loading**
Local authorities	0.650
UK government	0.890
European commission	0.824
Alpha Coefficient	***0.846***

when shopping for food?" Consumers reported on 8 different purchasing behaviours: choosing organic meat, choosing organic dairy products (milk/cheese/yoghurt), choosing organic vegetables, choosing fair trade, choosing locally grown food, avoiding buying products that have travelled a long way, choosing unpacked fruit and vegetables, and avoiding buying food that is not in season in the UK. Additionally, consumers were asked "Which of the following do you do nowadays when shopping for non-food?" Consumers reported on 6 different purchasing behaviours: choosing and using 'green'/natural cleaning products, choosing recycled toilet paper, choosing recycled stationery, choosing energy efficient light bulbs over tungsten/other bulbs, choosing sustainable clothing (i.e., organic cotton or hemp), and looking for optimum energy efficiency when buying electrical products/appliances. For each of these 14 behaviours, respondents reported "Always" = 3, "Often" = 2, "Occasionally" = 1, or "Never" = 0. The responses of the 14 consumer purchasing behaviours were summed to arrive at a respondent's overall green consumption index, which accounted for both the frequency and breadth of an individual's green consumption, and had a minimum possible value of 0 and a maximum of 42.

15.4.1.2 Independent Variables

We relied on three sets of independent variables that accounted for respondents' trust in sources to provide environmental information, personal knowledge about environmental information and, personal affect towards the environment. We elected to use climate change as our environmental application because it is a critical environmental problem affecting the global environment (IPCC 2010), and has received significant media attention in recent years.

To measure respondents' trust of government, environmental NGOs, scientists, friends/family and private sector companies to provide information related to climate change. Related to trust of government sources, respondents were asked "How much do you trust your local authority, UK government, and the European Commission, to provide you with information on climate change." For each government entity, respondents indicated "No trust at all" = 1, "Little trust" = 2, "Neither" = 3, "Trust a little" = 4, "Trust wholly" = 5. The three government variables were entered into a common factor analysis. One factor emerged to account for government trust, as seen in Table 15.1. To measure respondents' trust of environmental NGOs, friends/family, private sector companies, and

Table 15.2 Climate change knowledge factor analysis[a]

	Factor loadings	
Climate change knowledge—"How familiar are you with each of the following terms. . ."	General Knowledge	Action-based Knowledge
Climate change	**0.854**	−0.157
Carbon or CO2 emissions	**0.853**	0.195
Carbon offsetting	0.406	**0.663**
Carbon labelling	0.274	**0.642**
Alpha Coefficients	***0.922***	***0.779***

[a]Loadings stronger than ± 0.50 are bolded

scientists, respondents were asked "How much do you trust the following entities to provide you with information on climate change." For each entity, respondents indicated "No trust at all" = 1, "Little trust" = 2, "Neither" = 3, "Trust a little" = 4, "Trust wholly" = 3.

The second set of independent variables measured respondents' personal knowledge about climate change, we considered respondents' general and action-based knowledge. General knowledge relates to respondents' understanding of climate change terminology, whereas action-based knowledge relates to respondents' understanding of the activities that reduce climate change. To measure both types of knowledge we relied on one survey question that asked: "How familiar are you with each of the following terms." The general knowledge terms related to "climate change" and "carbon or CO2 emissions," whereas action-knowledge terms related to "carbon offsetting" and "carbon labelling." Respondents indicated whether for each of these items they "Have never heard of it" =1, "Have heard of it but don't know anything about it" = 2, "Know a little about it" = 3, "Know a fair amount about it" = 4, "Know a lot about it" = 5. The four knowledge variables were entered into a common factor analysis. The results were consistent with our expectations in that two factors emerged to account for our two types of climate knowledge: general knowledge and action-based knowledge, as seen in Table 15.2.

The third set of independent variables measured respondents' personal affect towards climate change. To assess respondents' sense of personal risk related to climate change, we relied on a survey question that asked "To what extent do you feel that you will be personally affected by climate change?" Respondents indicated whether they thought "I don't feel worried as I don't believe climate change is happening" = 1, "climate change is not happening yet, but my grandchildren will experience the effects of it in their lifetime" = 2, "climate change is not happening yet, and I don't think I will see the effects of it in my lifetime" = 3, "climate change is not happening yet, but I think I will see the effects of it in my lifetime" = 4, "I do feel at risk from climate change: it is happening now and we should do more to prevent it" = 5. To measure consumers' sense of empowerment about climate change, we relied on one question that asked respondents, "Please indicate the whether you agree or disagree with each of the following statements." Respondents were presented with the following two declarations: "There is no point in trying to reduce emissions at an individual level," and "I don't see why I should take action

Table 15.3 Sense of empowerment factor analysis

Sense of Empowerment about Climate Change—"Please indicate the whether you agree or disagree with each of the following statements..."	Factor loading
There is no point in trying to reduce emissions at an individual level	0.640
I don't see why I should take action on climate change if other people are not	0.643
Alpha Coefficient	***0.697***

on climate change if other people are not." Respondents indicated whether for each of these statements that they "Strongly disagreed" =1 "Somewhat disagreed" = 2, "neither agreed nor disagreed" = 3, "Somewhat agreed" = 4, "Strongly agreed" = 5. The two empowerment variables were entered into a common factor analysis. As anticipated, one factor emerged to account for empowerment, as seen in Table 15.3.

15.4.1.3 Control Variables

Because the context of the consumption decision is important (Hand et al. 2007), several control variables were included. Since scholars have argued that more educated individuals, on average, place more importance on eco-information and are more likely to trust eco-labels (Noblet et al. 2006) we controlled for consumers' education. Additionally, we controlled for the number of children respondents had at home, as environmental concern tends to increase in homes with children. Since social consciousness tends to increase with income (Huang et al. 1999), we added a control variable to account for consumers' household income. Additionally, we controlled for respondents' gender, as women tend to be more socially conscious (Huang 1993; Laroche et al. 2001; Virden and Walker 1999). Finally, we controlled for respondent's age (Anderson and Cunningham 1972; Lee 2008) and country of residence, such that England was the excluded country variable.[5]

15.4.2 Empirical Models

Table 15.4 includes descriptive statistics and correlations for all variables. It indicates that while correlations among our explanatory variables were within the range of acceptability in that they were less than .80 (Kennedy 2003). We also evaluated the

[5] It is important to note that in studying consumers' green purchases, no demographic variable is without controversy. For instance, van Kempen et al. (2009) found empirical evidence that low income consumers may be ready to make pro-ethical choices in the market place, in part because more options are available. Other studies have found that education, gender, age, and country of origin had no statistical relationship with green purchasing (Markard and Truffer 2006). Similarly, Oates et al. (2008) report that demographic variables have inconclusive results in predicting green consumption. However, because of the mixed and inconclusive findings, we have included the most widely recognized demographic variables in our statistical models.

Table 15.4 Correlations* and descriptive statistics

	(1)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(20)
(1) Total green consumption	1.00																	
(2) General knowledge	.173	1.00																
(3) Action-based knowledge	.262	.265	1.00															
(4) Risk	.260	.122	.002	1.00														
(5) Sense of empowerment	.281	.227	.087	.317	1.00													
(6) Trust of government info.	.116	.042	−.046	.233	.250	1.00												
(7) Trust of NGO information	.208	.087	−.082	.373	.348	.421	1.00											
(8) Trust of priv. business info.	.010	−.106	−.017	.071	−.034	.481	.197	1.00										
(9) Trust of scientific info.	.049	.170	−.004	.225	.265	.438	.524	.260	1.00									
(10) Trust of family/friend info.	.098	.031	−.044	.171	.128	.180	.287	.176	.175	1.00								
(11) Gender	.136	−.086	−.155	.148	.088	.087	.192	.083	.057	.103	1.00							
(12) Age	.091	.086	.072	−.041	.042	−.104	−.023	−.098	−.057	−.110	−.040	1.00						
(13) Education	.099	.168	.209	.016	.106	.045	−.033	−.092	.068	−.073	−.124	−.029	1.00					
(14) Household income	−.011	.089	.115	−.015	.042	.054	−.049	−.011	.041	−.042	−.156	−.098	.283	1.00				
(15) Number of kids at home	−.003	−.066	−.055	.061	.019	.035	.055	.034	.031	.120	.090	−.348	−.099	.018	1.00			
(16) Wales	.052	−.039	.002	.019	.008	.014	.021	.022	−.007	.008	.039	−.060	.003	−.022	.078	1.00		
(17) Scotland	.005	−.015	−.006	.003	.030	.053	.000	−.041	.001	−.038	.005	.109	.067	.016	−.054	−.069	1.00	
(18) England	−.035	.040	.003	−.016	−.029	−.052	−.013	.019	.005	.026	−.028	−.050	−.054	.002	−.007	−.601	−.752	1.00
Mean	17.28	0	0	2.69	0	0	3.34	2.37	3.50	3.31	1.53	45.09	2.83	3.70	1.69	0.05	0.08	0.87
Standard deviation	7.13	0.89	0.74	2.06	0.73	0.92	1.13	0.96	0.99	0.959	0.5	16.13	1.20	2.09	1.06	0.22	0.27	0.34
Min	0	−3.06	−1.83	1	−2.01	−1.55	1	1	1	1	1	16	1	1	1	0	0	0
Max	42	1.77	1.49	6	0.92	1.92	5	5	5	5	2	75	4	11	7	1	1	1
N	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513	1,513

*Correlations above ± 0.051 are statistically significant at $p < .05$

variance inflation factors (VIF) for each of our explanatory variables. The results revealed the highest VIF was 1.92, which was well below Kennedy's (2003) maximum acceptable threshold of 10.0 indicating that multicollinearity was not a concern. We used linear regression to evaluate our model, with robust errors. Statistical analyses were performed using Stata 9.2.

15.5 Results

The results of each of our estimations (see Table 15.5) show that the likelihood ratio test statistics were significant at $p < 0.01$, indicating that the null effect of the independent variables could be rejected. The R-square for our model was .2472, suggesting a reasonable model fit.

In examining the relationship between consumers' trust in different entities to provide climate change information and their increase in total green consumption,

Table 15.5 Factors related to consumers' green consumption[a]

	Total green consumption	
Variable	Coef.	SE
Trust of sources to provide information		
Government	0.469**	0.231
Environmental groups	0.824***	0.206
Scientists	−0.879***	0.215
Friends/family	0.275	0.203
Private business	−0.075	0.210
Personal knowledge		
General climate change knowledge	0.580***	0.222
Action-based climate change knowledge	2.478***	0.249
Personal affect		
Sense of personal risk related to climate change	0.554***	0.083
Sense of empowerment to address climate change	1.473***	0.290
Controls		
Gender	1.937***	0.379
Age	0.039***	0.012
Education	0.343**	0.160
Household income	−0.097	0.090
Number of kids at home	0.090	0.163
Wales	0.884	0.838
Scotland	0.013	0.564
Constant	12.661***	1.549
N	1,278	
F (17, N)	362.93***	
R-squared	.2472	

[a]Model was estimated using linear regression with robust errors; excluded country dummy variable is England

***p < 0.01, **p < 0.05

government trust was positive and statistically significant ($p < .05$), as was environmental groups ($p < .01$). Combined, these results offer some evidence in support of Hypothesis 1. However, consumers' having *less* trust in scientists to provide information about climate change was associated with greater total green consumption ($p < .01$), and there was no statistically significant relationship with friends and family.

Our results also showed that individuals who distrusted private business were no more likely to increase their total green consumption. These results offer support for Hypothesis 2. Additionally, our results showed a significant relationship between consumers' personal knowledge and buying green. More specifically, respondents' general and action-based knowledge of climate change were associated with greater amounts of total green consumption ($p < .01$). Combined, these findings offer evidence in support of Hypothesis 3, which states that consumers with greater knowledge related to climate change are more likely to buy green.

Finally, consumers' personal affect about climate change was related with their total green consumption. That is, consumers' sense of personal risk related to climate change ($p < .01$), in addition to their sense of personal empowerment to address climate change ($p < .01$), were both positively related with green consumption. These findings support Hypothesis 4, which suggests that consumers with greater personal affect related to climate change are more likely to buy green.

Related to our control variables, women were more likely ($p < .01$) to buy green, as were older consumers ($p < .01$). Additionally, higher education levels were related ($p < .05$) to greater overall green consumption, as were consumers that resided in Wales as compared to England ($\mathrm{p} < .01$).

15.6 Discussion and Conclusions

While consumers are becoming more knowledgeable about the environment and reflecting this knowledge in their decisions to buy green products, previous research highlights how little we know about the reasons why consumers chose to buy green. Since earlier scholarship has generally examined green consumption related to a single product label (Perrini et al. 2009; Loureiro et al. 2001; Teisl et al. 2002; Sammer and Wüstenhagen 2006; Mills and Schleich 2009), numerous questions exist about why consumers buy green across a variety of products and services (Galarraga-Gallastegui 2002).

This study advances our knowledge on the topic by examining individuals' total green consumption as it relates to their trust of various sources to provide them with environmental information, environmental knowledge, and personal affect towards the environment. In particular, we examine claims that sources of environmental information are critical to understanding green consumption because consumption may increase if trusted information sources were available (Young et al. 2010; Knott et al. 2008). Our results offer support for this notion in that we found evidence that consumers who have greater trust of government and environmental NGOs are more likely to increase their total green consumption.

By contrast, consumers who had *less* trust of private business to provide environmental information were no more likely to increase their total green consumption. This relationship exists, we believe because of scepticism about the motives of private business to market their green products. At issue is that private business may derive an economic benefit by symbolically changing their products to create the public perception that they are green, rather than radically changing their production processes to create truly green products. As such, consumers appear to pay little attention to companies' green marketing messages.

These findings have important implications to public policy and environmental NGOs in that a growing number of consumers are showing interest in understanding how to choose more environmentally friendly items (Maciag and Hepting 2008), but finding it difficult to translate this interest into action. Our findings indicate a strong relationship between consumers who trust government and environmental NGOs to provide environmental information and their green consumption. These results suggest the importance of providing information to the public about environmental matters and educating them about eco-labels. Additionally, these findings point to the value of government and environmental NGOs gaining consumer confidence in their ability to provide accurate environmental information. Related to government efforts, greater consumer credibility may be achieved by providing stronger guidelines regarding environmental advertising claims, and stronger regulation of such claims in an effort to prevent a green washing (Young et al. 2010). Doing so may encourage more widespread green consumption. This issue is particularly important because a small proportion of consumers who use environmental information in making their product purchases can go a long way towards encouraging the broader population of firms to change their production decisions in an environmentally friendly way (Moorman 1998), and the societal benefits of such a shift could be profound.

Related to private business, our findings indicate that its self-promoted environmental claims are largely impotent. That is, the environmental information put forward by private business has no meaningful effect on these consumers' product purchases. As such, eco-friendly business may benefit to a greater extent by relying on eco-labels to market their green products rather than self-promotion. Additionally, since consumers that trust government and environmental NGOs are more likely to buy green, businesses developing green products may benefit to a greater extent by partnering with these entities to advance their green strategies and products. Doing so may enhance the overall social legitimacy of their green approach.

These notions relate to our second set of findings—that personal knowledge about environmental matters is related with more green consumption. Such knowledge can be general in nature, in that it relates to a rudimentary awareness of basic terminology and concepts. However, knowledge that is action-based knowledge, in that it relates to consumers' understanding of the activities required to mitigate environmental problems, is more strongly related to overall green consumption. Additionally, consumers who have a stronger sense of personal risk regarding the environment and a sense of empowerment to mitigate it are likely to buy more green products. Combined, these findings point to the importance of environmental education. To see a widespread change in consumer behaviour, consumers likely require more information about environmental problems, how these problems are mitigated. Consumers also need more information about how they are personally connected to mitigation efforts. Our results further suggest that government and environmental NGOs would be more successful at undertaking these education efforts. In addition to typical educational approaches of informing the public through written materials, one novel education approach that may be particularly successful is rely on peer leaders. Since friends/family were more likely to influence eco-label users and potential eco-label users, relying on peer leaders within communities to educate their networks may be useful at increasing consumer knowledge about their environment and how they can act to reduce their impact.

In sum, while internationally consumers are becoming more savvy about the environment and increasing their consumption of environmentally friendly products (Darnall 2008; Perrini et al. 2009), many questions have remained about why individuals buy green. Utilizing multiple regression methodology for a large sample of UK residents, this research offers broader generalizations regarding consumers' overall green consumption. We show that individuals' green consumption is related to their trust of various sources to provide them with environmental information, environmental knowledge, and personal affect towards the environment. These findings have important implications about future scholarship, policymakers, and private business alike as greater efforts are made to encourage more widespread green consumption.

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Chapter 16
Conclusion: The Green Way Forward?

Diego A. Vazquez-Brust and Joseph Sarkis

Abstract Challenges and strategies related to Green Growth transitions are occurring globally. European and Asian regions of the world play a very considerable role in these transitions. This final chapter provides a closing to the book with contributions clearly identified. The chapter highlights insights and linkages within the book as well as providing areas for further research. We make a distinction between "Greener Growth" and "Deep Green Growth". Greener Growth is conceptualised as a policy focused version of sustainability where the environmental impacts of growth are minimised by making investment in the Environment a driver for economic growth. Deep Green Growth is anchored in sustainability science and defined as the increase of all economic activity that is not harmful to natural and social capital. We argue that Deep Green Growth is possible, and see 'Greener Growth' just as the start of the journey towards radical change in the design of consumption and production systems.

Keywords Green Growth • Sustainable production and consumption • Indicators • Sustainability science • Eco-innovation

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16.1 Introduction

This book examines in detail challenges and strategies related to Green Growth transitions. The concerns of decoupling economic from environmental performance have gained increased attention as various developing countries have started to become important contributors to the global economy. At this time we are seeing a number of concepts become realities as countries have focused their policies more directly on improving both environmental performance and international economic competitiveness. Currently there is a lack of literature that brings these issues to the forefront in a single compendium of writings. This book therefore, integrates, side-by-side, various Green Growth efforts occurring in different regions of the world – and most notably from Europe and the Asia.

This text provides an opportunity for knowledge sharing and capacity building across these regions of the world. No book can exhaustively cover all the issues that need to be addressed, although it is hoped that this contribution provides a comprehensive outlook of Green Growth; and therefore, contributes to the growing body of research into environmentally sustainable capitalism by focusing analysis on success factors and obstacles of such an approach. It draws on research approaches to explore the structural conditions required for economic growth to be compatible with environmental sustainability and how the transition to the new economy should be managed.

The book draws significantly on issues discussed and presented at the GIN 2010 conference 'Climate Change and Green Growth: Innovating for Sustainability'. These select chapters from the conference explored the relations between economic and environmental factors through a range of policy interventions and business models. A portion of these papers analyse cases in East-Asia, while a second group drew lessons from case studies in Northern Europe.

The success of climate change mitigation will depend on the collaboration of all global actors and, currently, the focus of attention is beyond the US and Europe (Zakaria 2011). Major infrastructure projects are located in the 'Post-American World' including Korea and China, and it is unlikely that any pathway to a green economy can be successful without Asian support. In East Asia, transformation commenced with endorsement of Green Growth by the 5th Ministerial Conference on Environment and Development in Asia and the Pacific (MCED-5) in 2005. The speed of regional 'greening' has accelerated since South Korea started a 'Green Growth Revolution' – aligned with the OECD's 'Green Growth Strategy'. The "Low-Carbon, Green Growth National Vision" was declared by Koreas' presidency in 2008, and swiftly followed in 2009 by a comprehensive "Green Growth National Strategy and Five Years Plan" with a planned investment of 83.6 billion US dollars. The country's 'green commitment' is more impressive considering that at the time of Kyoto agreement negotiations, Korea had refused to sign the Annex I invoking its classification as a "developing country".

A second group of contributions in this book draws lessons from case studies in Northern Europe, where attempts to move towards a Green Economy have been pursued locally for many years; although perhaps where substantive progress has been slower than in East Asia.

The selection of chapters also aimed to provide insights into the three main areas where transitions should be consistently managed: government policies, business initiatives and household consumption patterns. There are many threads connecting the chapters and many ways in which the chapter could have been grouped, thematically, geographically, methodologically, and by stakeholders. Since the focus of the book is on lessons learned, we grouped the chapters in areas where such lessons can be applied: national policy analysis; tools and indicators, case studies of industry-firm level incentives and disincentives for Green Growth, global context analysis, case studies of household level incentives and disincentives for Green Growth.

We now summarily review the chapters for the reader.

Chapter 1, Introduction, argues that game-changing Green Growth must be rooted in economic approaches allowing for the inherent complexity of human-environment relationships. It needs to be implemented through multi-stakeholders and multi-scale governance arrangements and fuelled by policies and managerial techniques promoting synergies rather than just decoupling-environment and economic growth. The chapter first outlines the evolution of how desirable relations between growth and environment have been conceptualised: from the debate about zero-growth vs. uncontrolled growth, to sustainability and parallel discourses emphasising principles such as ecological modernization and the win-win paradigm. The chapter then describes the emerging discourse of Green Growth and positions the discourse in the context of its predecessors. It also summarises transition challenges and provides an overview of the diverse ways that environmental issues have been utilised in the management literature. The chapter presents a framework conceptualising ten main, intimately related, dimensions of Green Growth transitions:

1. Quality of Growth
2. Policy Integration
3. Multi-Stakeholders Governance
4. Flexible Regulation and Dynamic Policy Mix
5. Competitiveness
6. Virtuous Circles: Adding Value
7. Social Cohesion: Inclusion and Justice
8. Trust and Collaboration
9. Entrepreneurship

These transition dimensions are in turn intertwined with the three core drivers or engines of Green Growth: innovation (technological but also social); globalisation (economic but also cultural and institutional); and ecological urgency.

The interaction between the nine transition dimensions and three drives will result in a variety of possible trajectories, more or less successful, towards a Green Growth economy. Figure 16.1: Green-Growth Transitions combines the concepts

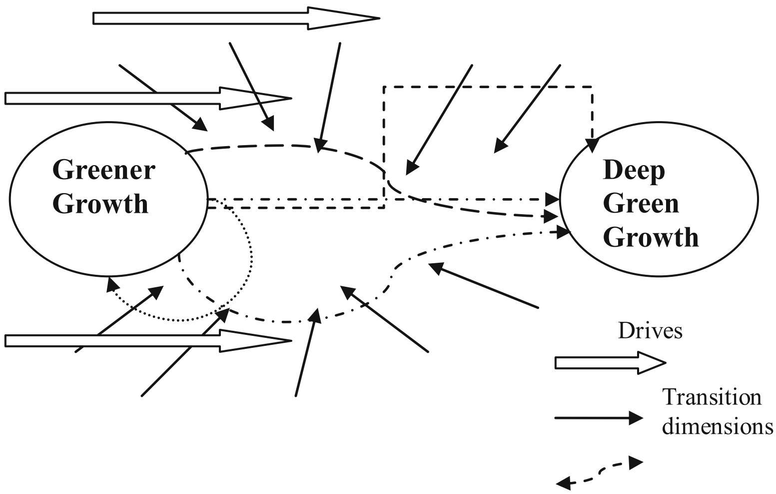

Fig. 16.1 Green growth transitions

summarised above with socio-technical transition theories, and aims to summarise the integrative framework. Such a framework proposes that the current policy-mix and strategies are only the initial stage (Greener Growth) in an evolutionary economy moving towards Green Growth. This may evolve along a variety of alternative patterns associated with technical change and characteristic forms of economic organisation, competition and cooperation. The final configuration of such trajectories will depend on the dynamics between the drivers of Green Growth and the transition dimension. This is not a sudden process but one that happens gradually until a new paradigm crystallises.

The subsequent chapters in the book analyse one or more of these transition dimensions and its effects on Green Growth. In particular the policy analyses presented in Chaps. 2, 3, and 4 provide a comprehensive assessment of different aspects related to these transition dimensions through different conceptual lenses.

16.2 Analysis of Green Growth Policy and Regulation

Korea's low-carbon Green Growth national strategy was analysed in **Chap. 2**, *A Critical Review and New Policy Framework of Low-Carbon*, *Green Growth Strategy of Korea*, by Rhee, Jang and Chung. The chapter summarised the prominent characteristics of the contents and processes of the national strategy, identifying strengths contributing to its current success; as well as possible threats to its continuity. The Green Growth strategy successfully leverages a historically high level of ***trust*** between the private and public sector, and fully exploits cooperative governance structures built during Korea's era of strong economic development. In addition most plans include ambitious goals and ***integrate relevant***

policy areas and well-known intervention alternatives. This includes a focus on strengthening ***social-cohesion*** through distributive measures such as plans to eradicate 'poverty energy' and the recuperation of natural infrastructure.

However, the strategy fails to deploy a truly ***multi-scale, multi-stakeholders' governance approach***. The focus on collaboration between the government and large companies (chaebols) excluded the views of stakeholders from SMEs, local authorities, and environmentalists which criticised the strategy as "green wash." Other weaknesses include a ***policy mix*** more oriented to sustaining strategic competitiveness than to understanding life in low-carbon society. As a result, the policy-mix has insufficient emphasis on bottom-up behaviour change, individual ***entrepreneurship***, and embedding ecological values in the society. The lack of an eco-centric vision is further reflected in apparent lack of ecological indicators (i.e. carbon footprints) during the planning process. In turn, ***regulation*** has failed to address measurement of carbon-emissions and, – critically, to provide clear market mechanisms depending on cap-and-trade industrial emissions. A challenge to the ***competitiveness*** of the strategies is that economic and environmental consequences of policy are influenced by changing interactions in markets and society; and thus policy needs to be informed by (currently lacking) in-depth dynamic analyses of the changing world, including market dynamics, technological innovation, industrial responses, and changes in socio-cultural values.

The authors suggest a new framework to help realise the country's ambitious vision and goals, so all these weaknesses can be addressed in the subsequent refining of plans during the implementation of the strategy. The chapter emphasises that Low carbon Green Growth (LCGG) strategies need to be able to manage disruptive changes in business and **technology platforms** and adapt to **global dynamics**. There are significant competitive uncertainties among alternative technological platforms, which are interconnected in complex global supply 'grids', thus the authors proposed a multi-sided market competition model to help analyse the dynamics of this phenomenon. The chapter argues that every national Green Growth strategy must take into account policy effects not only within the country's borders, but also from global supply chains.

Chapter 3, *Greening the Korean Stacks Through Lessons from the EU Emission Trading System: A Socio-legal Analysis* is written by Hyonsu Kim, from the Ministry of Finance in Korea and Radoslaw Stech. This chapter focused on a key element in Green Growth ***policy mix*** and ***regulation***: the need to provide clear market mechanisms depending on cap-and-trade industrial emissions lessons (emphasised in Chap. 2). The chapter focus on drawing lessons from the EU Emission Trading System (hereafter EU-ETS) to inform the emerging and dynamic South Korean Emission Trading mechanism (hereafter SK-ETS).

EU-ETS is the largest emission trading system in the world, both in terms of trade volume as well as its geographical scope. It provides an important benchmark for analysing emerging trading schemes beyond the EU. The authors observe that EU-ETS succeeded in laying the foundations for a secondary market and – to some extent – also achieved its environmental goals. However, the process was long, costly and resulted in numerous market disturbances. In order to gain a deeper understanding of these problems, the chapter analysed the institutional and regulatory mechanisms of EU-ETS drawing on a framework identifying five crucial principles underpinning an effective emission trading system: scarcity, credibility, simplicity, tradability and integration. The same framework is applied to analyse the legislative and institutional development of the incipient SK-ETS. It became clear that the current design of the scheme could create challenges similar to those encountered in Europe. The authors noted, through interviews with key stakeholders in Korea, conflicts in the Korean government over the scheme's leadership and ingrained industrial opposition to emission trading. To some extent, the lack of definition around SK-ETS is creating a divide in the tradition of ***trust*** in governmental strategies and public-private consensus over policy in Korea. A litigation threat over the future developments of the scheme exist, unless the current conflicts are not resolved through ***multi-stakeholder governance*** mechanisms such as informed mediation and consultation. All in all, the authors conclude that emission trading schemes have great potential to contribute to sustainable Green Growth. Yet, as the European case illustrates, the establishment of the scheme can be extremely costly at the initial stage.

Chapter 4, '*Sustainability Science Integrated Policies Promoting Interaction-Based Building Design Concept as a Climate Change Adaptation Strategy for Singapore and Beyond*', by Kua and Koh, is a policy analysis of Singaporean climate change strategies in the building sector. It is also a methodological chapter that presents a participatory tool and research strategy to help embed principles of sustainability science in the design of integrative policy elsewhere. The study is motivated by the emphasis placed by the latest IPCC report that a complete climate change strategy must consider both the mitigation and adaptation of climate change.

The Singapore National Climate Change Strategy (NCCS) includes both these strategic aspects. However, although the NCCS contains broad directions and statements on adaptation, there is almost no mention at the national level of the detailed strategies to adapt building stocks and infrastructure to possible consequences of climate change. The authors set out to uncover what local industry experts think are the most likely effects of and strategies to meet climate change consequences in Singapore. "Integrative", "participatory", "place-based" and "reflective" elements of sustainability science research are used to propose integrated policy addressing climate change mitigation and adaptation. The authors conducted a Delphi study using a panel of Singapore's building and construction industry professionals. The results showed that a majority could not clearly distinguish between mitigation and adaptation strategies, and the solutions they proposed for combating the likely consequences of climate change were incoherent. Based on this observation, an integrated interaction-based design concept for construction was proposed by first characterising the problem with three design elements – water, soil and built environment. Various policy strategies were then proposed and combined with the help of four integrated policy strategies aimed at promoting adaptation measures for the building industry. The authors note that the aforementioned integrated policy strategies are not exhaustive in and of themselves. They should serve as examples of how different information derived from their Delphi study can be utilised for actual policymaking. Finally, the chapter proposes a generalised framework of analysis and development of integrative policy that can be applied to most other countries.

16.3 Tools and Indicators to Measure Green Growth

The first chapter in the "tools and indicators" category is Chap. 5, *Analysis of Technical Efficiency and Productivity Using Meta-frontier – Manufacturing Industries in Korea and China – by Kang and Kim.* The chapter developed and tested a methodology to compare the technical efficiency, technology gap and productivity[1] of manufacturing industries in Korea and China. More concretely, the authors propose a methodology and indicators to assess the progress of China and Korea effort to transform their industrial structures for the stimulation of green economic growth and green industries. The chapter proposes that the degree of changes needed for successfully greening an industry can be measured in terms of existing environmental efficiencies and productivities and describe a methodology to assess the influence of environmental factors on the ***competitiveness*** of manufacturing industries across countries. Through this, they expect to confirm which country is closer to sustainable growth.

The authors use a Meta-frontier analysis to compare 'pure' technical efficiency – ignoring the polluting effects of technologies – with environmental technical efficiency – that accounts for pollution effects. The results show that reducing pollutants and increasing desirable outputs simultaneously is more challenging to China than it is to Korea, since Korean firms' productivity is higher on average than Chinese firms' productivity (both ignoring and considering pollution effects). Thus, the authors argue that Korean manufacturing is closer to Green Growth than Chinese manufacturing. The analysis argues that if environmental regulations are gradually strengthened with the reinforcement of international environmental regulations in China, Korea will have a competitive advantage over China because of the increasing environmental cost in Chinese manufacturing industries. The superior technical efficiency of Chinese manufacturing will eventually offset Korea's advantage. The outcome is that Korean manufacturing industries need to differentiate themselves by seeking higher quality through technical innovation, and specialising in areas of technology such as medical and precision, audio-visual, motor vehicles, machinery and equipment, and electrical machinery.

Ultimately, the chapter emphasises that for the sake of the environmental and economic development of the region, both Korean and Chinese firms must devote

[1] Technical efficiency measures a relative ratio between a maximum output and actual output under given inputs. Productivity not only measures the amount that was produced, but also the ratio of output produced to the input used. Thus, productivity is an important element influencing a firm's sustainable growth and competitiveness.

themselves to Green Growth; and thus move away from a sole concentration on economic output. By the same token, manufacturing industries in the two countries should move away from polluting and the energy-intensive practices, towards more high-tech and service oriented activities.

Chapter 6, '*Green Growth Index and Policy Feedback*', by Han, Kim and Lim provided empirical tools to dynamically measure progress towards Green Growth. The authors argued that ***flexible and dynamic regulation*** is essential to the success of Green Growth strategies. The crucial question in the definition of national Green Growth strategies is the stringency of the country's environmental policy/regulation. Strong regulation stimulates environmental innovation but, if the stringency of standards is not adequately calibrated, regulation can became an obstacle to ***competitiveness***. To avoid economic underperformance with stricter environmental regulations, the government needed to design and implement a smart ***policy package*** that is dynamically relevant. In turn, policy-feedback from dynamic indicators is essential to adjust the policy mix and respond to /anticipate social and economic trends. Economic growth and environmental performance should thus be measured and evaluated in a dynamic context.

Currently, Korea does not have such a dynamic evaluation tool; the chapter provided a system dynamics model that can be used as a basis for measurement and policy feedback for Green Growth as a national strategy. The model took into account economic, social, environmental and institutional variables, to analyse the gap between current or realised rate of investment in the environment (all environment-related investments including the cost incurred due to the environmental regulations) and the optimal rate of investment (the rate needed to maintain the economy in a path of optimal Green Growth). The normalised gap between these two rates is called the 'Green Growth gap.' This gap gauges how much the current growth path deviates from the optimal dynamic path. The model is tested with data from Korea for the period 1990–2009. The results suggest that Korea's dynamic growth has not followed the optimal growth pattern in terms of economy and the environment. The country and society invested less than required to sustain a dynamically optimal level of Green Growth. The authors suggested that policy should give more emphasis to investment for the future – environmental regulations and technologies – and less to policies encouraging the wants of present generations, particularly with regard to consumption. If the gap widens, this is a signal that environmental investment should be strengthened further.

16.4 Impacts of Multinationals on Global Green Growth

The next two chapters clarified the extent greener growth in the more developed industrial economies in Europe, North America and Japan – and also new emerging economies such as South Korea and Singapore – have only become environmentally cleaner at the expense of emerging economies. Their success may be due to exporting polluting elements of their economies transferring the negative results of economic growth to developing countries.

In transnational supply chains, no single country can regulate the whole supply chain; therefore measurements of accumulated impacts along the chain are not compulsory and pollution flows difficult to trace. The potentially most polluting sectors – such as those in the chemical, extractive and automotive industries – are privately regulated by voluntary industry standards and global codes. These standards and codes demand collection of data along the supply chain, and therefore, can be subjected to integrated assessment as presented in Chap. 7 for two automotive supply chains.

Chapter 7, '*Environmental Impacts of Korea-Europe Automotive Supply Chains; Moving Towards a More Sustainable Model*' by Nieuwenhuis, Choi & Beresford maintains the focus on East Asia, but shifts to a meso-level analysis at a global scale. The Automobile Industry is one of the most global of all manufacturing industries but also an industry where the state has played an extremely important role in its evolution. The question of how growth can be reconciled with sustainability is particularly pertinent in the case of cars which are fossil-fuel dependent and environmentally polluting. The chapter filled a gap in the existing body of research on environmental impacts of the automotive industry. Both the impacts of vehicle manufacture and its use have been widely studied; but those of the logistics of new vehicle distribution less so. Japan and Korea together constitute the leading source region for shipped cars in terms of volume and carrier-miles generated. By implication, exported Japanese and Korean vehicles account for substantial amounts of GHGs as they travel; first by ship, then onward by rail or road. Loading and unloading cars under their own power generates additional impact. Recent years have witnessed a gradual transfer of production from the home countries of Asian firms – notably Japan and Korea – to locations nearer to recipient markets in USA, Europe and elsewhere. However, the environmental implications of such shifts in production location have not been widely considered. Environmental data have been combined with a transport cost model such that initial estimates of the environmental impact (in CO2 output) of Korea-Europe automotive supply chains may be made. This is compared with the impact of supplying the EU market from local transplant production.

The chapter focuses on an analysis of Kia and Hyundai supply chains, contrasting the conventional route from Asian factories to Western Europe whereby shipping is the principal mode, with the alternative of trucking cars from the new locations in East Europe. Against the authors' expectations, the latter is shown to have a significantly lower impact. The authors findings have implications for future location decisions of car factories and – potentially – other manufacturing facilities, as well as raising wider questions about the long term viability of the globalised car system in favour of some more localised solutions. The chapter's results show the positive impact of globalisation shifts which – according to Dicken (2007) – are influencing east-Asian car companies to re-allocate production closer to customers in key global markets in order to retain regional competitiveness by upgrading their business models from export- to FDI[2]-oriented. Thus, suggesting that – at least in the automotive industry- internationalisation forces can be an ally of globalised Green Growth.

Ninety-seven percent of all FDI comes from developed countries (plus Korea, China, Taiwan and Singapore), thus providing support to the 'pollution export hypotheses' that argues that FDI flows from developed countries to 'pollution heavens', if the FDI is for 'dirty industries'. However, only about one third of total FDI goes to developing countries (Dicken 2007). The global economy shows a dominant pattern of cross-investment between the more developed economies, or a pattern of investment of less developed economies in more developed ones. These patterns provide little support to the 'pollution haven' hypotheses. An exception to this pattern are the mining industry and to lesser extent the chemical industry. In these industries, productive activities of Multinationals are mostly located in developing countries and the likelihood of 'passing on negative effects is higher', therefore more studies are needed to investigate the behaviour of Multinational in these sectors. Chapter 8 helps us to move in this direction.

Chapter 8, '*Strategic Responses of Multinational Corporations to Environmental Protection in Emerging Economies: The Case of the Petroleum and Chemical Sectors in Latin America and the Greater China Region*' by Fossgard-Moser, Tsai and Lu, looks at the effects of FDI in Green Growth. It examined the responses of multinational corporations (MNCs) to environmental protection issues in emerging economies in Latin America (the petroleum industry in Colombia and Peru) and Greater China (the chemical sector in Mainland China and Taiwan).

MNCs play an increasingly important role in the sustainable development of emerging economies as more developing countries adopt Green Growth policies. This chapter describes how the liability of foreignness imposed by local institutions on MNCs influences them to be more responsive to environmental protection issues than other types of companies. The implication is that FDI, in general, is beneficial to environmental protection in emerging economies. Through active engagement with local institutions MNCs play a key role in diffusing more advanced home country-originated technologies and management know-how.

Simultaneously, the chapter describes that when MNCs see good environmental performance as a source of potential **competitiveness** in a host country's market, they are more prone to deploy resources, environmental capabilities, and experiences based upon their global policies and practices. The research, however, suggests that MNCs are not consistent in their application of environmental policies and practices world-wide. The environmental performance of MNC subsidiaries is in practice closely linked to the local context of operation and any accompanying pressures — both formal and informal — for environmentally responsible business practice. In particular, the more stringent the local regulatory standards, even when there is little enforcement, the better the environmental performance of MNEs.

[2] Foreign Direct Investment.

The chapter shows that MNCs' responsiveness can be understood in terms of a combination of (external) regulative and cognitive and (internal) normative institutional pressures. The dominance of the former in the environmental performance of MNC subsidiaries illustrates how important it is for emerging economy governments to actively manage environmental impacts caused by MNCs and other company types operating within their jurisdiction.

16.5 Evidence of Virtuous Cycles Between Environmental and Financial Performance

The first few chapters assumed that Green Growth was possible and thus analysed the environmental consequences of a range of policies and industrial practices or explored the incentives and disincentives for its implementation. Chapter 9, '*Environmental Innovations and Financial Performance of Japanese Automotive and Electronics Companies*' by Cortez and Cudia, takes a step back and uses empirical analysis to investigate the assumption that environmental investment improves financial performance, drawing on a case study of the effects of corporate disclosure regulations in the automotive and electronics industry in Japan.

Sustainability reporting as facilitated by the Ministry of Environment's environmental accounting and reporting guidelines has been standardised in Japan for over a decade. Product and process improvements pertinent to environmental innovations are measured in environmental costs. Following literature on the resource-based view perspective, the chapter described the positive impact of environmental innovations on financial performance. Alternatively, the slack availability of resources perspective described the reversal effect of the relationship, i.e. financial performance positively affects investments in environmental innovations. Finally, it investigated the existence of virtuous cycles between the constructs and how tangible and intangible benefits accumulate within the context of greening businesses. Statistical tests using panel regression analysis reveal that environmental innovations have a linear relationship with the financial performance of Japanese firms included in the study. This specific results suggests that changes in corporate environmental innovation would result in a corresponding level of change in their sales, net income, assets, and long-term debt and equity. The chapter emphasises that there is much to learn from the Japanese environmental reporting, particularly how ***regulation*** play a central role in promoting sustainability.

The relations between growth, economic performance and environmental performance was the central theme of **Chap. 10**, '*Achieving Greener Growth: A Business Perspective for Proactive Commitment*', by Martinez, Vazquez-Brust, Zoakei and Peattie. This chapter examines the strategic integration of Environmental and Social Responsibility (ESR) into business operations. It contends that the enhancement of corporate productivity can be achieved via the symbiotic pursuit of green values and lean production practices. A framework is presented – drawing on contingency theory – to suggest basic requirements for successful symbiotic 'green and lean' relationships. The model proposes that a sustainable corporate action plan, enabling a strategic orientation of lean and green decision-making, draws upon five interrelated dynamic contingencies: corporate values, consumption, business benefits, legislation, and technology. The theoretical propositions are illustrated and extended using the case study of Adnams Brewery (Southwold, UK) – a company that has come to symbolise the benefits of adopting strong eco-friendly values to 'green' the business and its products. Drawing on in-site visits, interviews with the Managing Director and analysis of corporate reports, the case corroborates the idea of a symbiotic relationship or virtuous cycle of lean and green.

16.6 Studies in the Diffusion of Environmental Innovation, its Incentives and Disincentives

The aims of Chap. 11, '*Participatory Research on Green Productivity of Silk and Cotton Woven Products in the Northeast Region of Thailand*' by Wirojanagud and Promlao, are twofold. The chapter analyses the challenges of technology transfer and environmental innovation in SMEs in developing countries. It also reflects on the role of researchers and universities in the transition towards more sustainable economies; emphasising the need to be aware of the poor as a key stakeholder in the development process. The research project was designed to be in line with Green Growth, Sustainable Livelihoods (SLA) and Sufficient Economy concepts. It aimed to support vulnerable communities with a pro-poor development approach linking social and environmental sustainability. It was not a full technical research initiative but an example of action research using a participatory approach to search for scientific findings which enhance sustainable development. Participatory assessment allowed identification of the main constraints, opportunities and concerns encountered by entrepreneurs in poor communities. The action research was conducted at the household level in the northeastern region of Thailand during 2008 and 2009 with 83 entrepreneurs participating. The technology transferred to the entrepreneurs included cleaner technology and a wastewater treatment process. Integration of the appropriate transferred technology with the local knowledge resulted not only in more effective production processes, but also supported environmental sustainability. The chapter emphasised that the success of this type of initiative promoting sustainable entrepreneurship research requires strong cooperation among line agencies, local authorities and entrepreneurs.

Kortelainen, Ratinen and Linnanen' s Chap. 12 *Attitudes Towards Energy Efficiency and Renewable Energy in European Small and Medium-Sized Enterprises*, discussed a survey in eight European regional groups of SMEs. The context for the survey is a European project to organise a common energy agenda within regional groups of SMEs to tackle climate change by increasing energy efficiency and renewable energy use. The results show that attitude towards energy efficiency improvements seem to be more positive than that towards increasing renewable energy use. National and regional energy policies, markets and culture seem to have more influence on attitudes than the common goals of the European Union.

The chapter also described how seemingly non-value laden management techniques and knowledge influence the adoption of environmental technologies. For instance, the managers' extent of investment appraisal methods and activity-based costing techniques knowledge correlates with positive attitudes towards both energy efficiency and renewable energy. The authors argue that in the future, policy should pay more attention to the grass roots level of small enterprises and include bottom up approaches in their policy-mix, not only top down approaches. The finding that good cost management skills seem to be linked with energy management also supports this notion. In other words, good cost management can lead to interest in managing energy costs and thus additionally to better environmental performance.

However, the chapter points out important disincentives for investments in energy efficiency, particularly high risk aversion within enterprises. Energy is mainly seen as quite a minor cost factor and energy savings as a risk that could put production in danger. Thus, the authors recommend that policies should be directed to the SME's owner-manager. Attending to the peculiarities of entrepreneurs and analysing their energy behaviour – especially to reduce high risk aversion in energy investments – should bring energy efficiency and renewable energy closer to the core business of SMEs. The chapter noted the difficulty of targeting this group effectively with "one size fits all" policy-mix approaches. Policy-makers should try to identify different subgroups (innovators, early adapters, early and late majority and laggards) and target their particular policy needs. Accordingly, multi-stakeholders and multi-scale regulation and governance strategies accounting for a wider variety of perspectives and roles might be needed for the diffusion of environmentally sound technology.

Concerns about China's Green Growth competitiveness – as in Chap. 5 – are the focus of Chap. 13, '*The Diffusion of Green Technological Innovations and Stimulus: The Case of LUBEI Eco-Industrial Park in China*', By Li Guo. This chapter argued that China is facing a critical challenge due to its inability to cope with increased demand of green technological innovations in the post-crisis era. Due to the low level of the overall technology system and limited R&D capabilities of domestic enterprises, numerous techniques and equipment are required to be imported from developed countries in order to promote economic development. Therefore, the key issue is how to enhance the competitiveness of manufacturing industries and their export products through independent green innovations. However, the results of investment in green technologies are frequently hampered by the existence of institutional disincentives to upgrade existing technologies. The chapter analyses the evolution process of green technologies of the pioneering LUBEI Eco-Industrial Park in China and proposes policy recommendations that can be applied widely by transition economies around the world. It is necessary to distinguish the mechanism and regulations of green technological innovation, grasp the window of opportunity and increase the R&D investment on advanced green technologies in order to seek the first-mover advantage in international markets. Public policies, market drivers, organisational cultures and other stimulus also play key roles in the green technological evolution (as emphasised in Chap. 10) Therefore it is critical to make the mechanism of the stimulus clear and make full use of the stimulus of green technological innovation in order to avoid 'low-efficiency technology trap'.

Chapter 14, *The Practice of Innovative Energy Systems (IES) Diffusion in Neighbourhood Renovation Projects: A Comparison of 11 Cases in the Netherlands* by Hoppe, Bressers and Lulofs, sought to answer the question of which factors explain the application of innovative energy systems in renovation projects in residential areas. This issue is quite important as the diffusion and deployment of clean technologies in large energy consuming sectors is important to reduce substantial GHG emissions and therefore contribute to achieving Green Growth. An analytical framework was tested by conducting a comparative analysis between 11 residential sites in the Netherlands where neighbourhood revitalization projects were carried out. It includes six independent variables: (1) policy instruments, (2) housing associations, (3) local governments, (4) cohesion between actors, (5) inter-organisational collaboration between actors, and (6) contextual factors.

Three variables exercised a rather positive influence on the application of IES: policy instruments (climate policy), housing associations' organisational characteristics, and inter-organisational collaboration. With regard to the latter, the chapter states that without the presence of a highly motivated, authoritative person close to the decision making (the opinion leader), combined with frequent visits to thematic meetings, important information critical to the application of IES is not diffused. The role of local governments was rather limited, as they only exerted an influence in the planning stages of projects or played minor, supportive roles. Strikingly, the successful projects were all located in relatively small municipalities within which lay only lightly staffed local authorities that lacked the capacity to pay much attention to local climate policy, including the installation of IES in residential areas. Two contextual factors were important: a large total investment per dwelling, and policy support for urban renewal activity. The latter exerts a negative impact, and suggests that urban areas troubled by a plethora of problems, where ***social cohesion*** is low, do not provide optimum conditions for meeting environmental goals.

The authors seemed fairly sceptical of the deployment of IES technologies in the housing sector in the Netherlands. They point to a great divide between goal setting and goal achievement at the local level, where goals appear too ambitious, and the current ***policy mix*** is inadequate to gain commitment from key actors. In accordance with Chaps. 11 and 12 findings about SMEs, the chapter emphasises that research and policymaking should devote careful attention to the way local actors should be addressed in order to gain commitment and to see how local authorities may actively facilitate the project of furthering energy efficiency in housing renovation sites – not just by setting ambitious goals. Furthermore, systematic, in-depth comparison of local level projects, as well as international comparative analyses are necessary to assist the Dutch national government, the European Union and the OECD to develop strategies that encourage the ‘greening’ and better energy performance of domestic housing in current residential areas. It is up to these organisations to provide policy incentives that foster the further deployment of clean energy technologies in the domestic housing sector. This is important since the greening of energy usage is as a significant element of Green Growth.

16.7 Green Consumption

In Chap. 15, ‘*Why Consumers Buy Green*’, Darnall, Ponting and Vazquez-Brust analyse the purchasing behaviour of a large sample of UK residents and offer broader generalisations regarding consumers’ overall green consumption tendencies and their potential to buy green. Green Consumption is one of the aspects of Green Growth less encouraged by East-Asian government’s strategies. Nonetheless, wide-spread green consumption is essential for long term changes in the economy (as pointed out in Chap. 2). Darnall et al. show that individuals’ actual and anticipated green consumption is related to their trust of various sources to provide them with environmental information, environmental knowledge, and personal affect towards the environment. Combined, these findings point to the importance of environmental education. To see a widespread change in consumer behaviour, consumers likely require more information about environmental problems, how these problems are mitigated and how they are personally connected to mitigation efforts. The results further suggest that government and environmental NGOs would be more successful at undertaking these education efforts than business. In addition to typical educational approaches of informing the public through written materials, one novel education approach that may be particularly successful is to rely on ‘peer leaders’ (a similar recommendation is made in Chap. 14). Since friends/family were more likely to influence eco-label users and potential eco-label users, relying on peer leaders within communities to educate their networks may be useful at increasing consumer knowledge about their environment and how they can act to reduce their impact.

Related to government efforts, greater consumer credibility may be achieved by providing stronger guidelines regarding environmental advertising claims, and stronger regulation of such claims in an effort to prevent green washing. Doing so may encourage more widespread green consumption. This issue is particularly important because a small proportion of consumers who use environmental information in making their product purchases can go a long way towards encouraging pro-environmental changes in companies’ production decisions (Moorman 1998), and therefore the societal benefits of such a shift could be profound.

16.8 An Integrative Framework

The resulting insights gained from the research presented in this book are applicable to all regions of the world, whether they are developing or developed economies. The results are relatively encouraging in terms of Green Growth prospects, although the question is no longer whether the current capitalist model should be replaced by 'Green Growth' capitalism (or socialism), but what are the structural conditions required for this transition to be brought about and managed. Most cases identify the fundamental role of regulation and strong government leadership (Chaps. 2, 3, 4, 6, 8, 14, and 15) and it is the government that must set the bar using environmental standards (Chap. 6). If the bar is low, multinationals and local firms will only go beyond if they perceive a clear competitive advantage of doing so (Chap. 8). In turn, regulation is one of the predominant factors behind virtuous cycles of economic and environmental performance (Chaps. 9 and 10). An interesting thread within the chapters is the positive assessment of external impacts of Green Growth policy in developing countries. Chapters 7 and 8, provide robust empirical evidence of positive environmental effects out of current production trends in global supply chains (automotives, chemical and oil), thus countering arguments about developed countries "exporting" the more polluted parts of their economies.

Studies in East Asia point out difficulties in the implementation of Green Growth – due to path dependencies, a lack of clear policy in key issues such as emission trade mechanisms (Chaps. 2 and 4) or adaptation policies (Chap. 3) – but are mainly optimistic about the positive relationship between Green Growth and competitiveness (Chap. 5); or propose models to address identified problems (Chap. 2). In contrast, studies from Europe tend to be more sceptical about the political and institutional feasibility of Green Growth strategies (Chaps. 4, 12, and 14). Recurring issues in European cases are: the lack of integration of bottom up policies in the governance; the inadequacy of "one policy mix; the need for more participatory models of -*does-not* fit-all" policy and; the costs and lengthy times associated with the implementation of Green Growth policies. There is no European equivalent of the relationship of trust and public-private policy consensus found in Korea (Chap. 2), China (Chaps. 13 and 8) Taiwan (Chap. 8), Thailand (Chap. 11) or Singapore (Chap. 3).

The regional differences may be due in the dominant economic systems in each region. Communist countries may be better positioned to 'green' their economies (Jacobs 1991). In communism the State is involved in all decisions and the overall outcome of individual economic activities need not be governed by financial profit.

Indeed, drawing on a comparative capitalism analysis framework (Amable 2009), it can be argued that the stronger the levels of government intervention in market mechanisms, the better positioned an economy will be to be rapidly "greened". Thus, transitions to Green Growth will be easier in economic systems such as socialism, social-market capitalism and developmental capitalism, all of them giving importance to some kind of 'industrial policy', a great degree of social accountability of business and ideological emphasis on values other than efficiency.

The contributions in this book suggest that developmental capitalism economies such as Korea and Japan, have already formed the structural conditions required to make social inclusion compatible with growth, they may only need to decide the best strategy to adjust them to incorporate environmental concerns. Korea, for instance, successfully decoupled growth from social inequality from 1960 to 1990. They achieve it through a strong level of state involvement in the economy where ideological emphasis on ‘social cohesion’ is the main objective of economic development (Stiglitz 2002). This situation is translated in a series of highly interventionist measures including industrial policies and re-distribution measures such as land reform (Dicken 2007). Many of Korea’s state policies, in particular its tight controls of the financial sector, were dismantled during the 1990s (Stiglitz 2002). However, the central pillar of South Korea’s industrial policy, the coordination of investment for developmental objectives, has resurfaced in the country’s National Green Growth Strategy – discussed in detail in Chap. 2. Korea has committed 2% of its GDP in the pursuit of this strategy that is explicitly presented as the revival of the ‘old successful Korean Model’ (Shin 2009). Following the ‘old successful model’ the strategy is dominated by Government centrality, underpinned by concern for social cohesion/distributive justice (evidenced in the universal energy service for the poor, that makes government responsible to eradicate energy poverty by 2016), and translated into a policy mix reminiscent of those used to achieve socially inclusive growth. Korean policy mix is flexible and pragmatically adjusted; they explore policy options assembling seemingly contradictory alternatives. The elements of the policy-mix that don’t work are adjusted or dropped (Stigliz 2010).

As Chap. 2 highlights, decoupling growth from environmental deterioration might be more challenging than decoupling growth from inequality. Korean society is now more democratic and less likely to accept authoritarian, ‘closed door’, policies. Environmental deterioration processes are global in scale. Korea will still be affected by climate change if the country succeeds in fully greening its economy but world economies do not follow through. Further problems might stem from the main criticism presented in Chap. 2 that Korea’s National Green Growth Strategy lacks ‘deep green’ values and truly multi-scale, multi-stakeholders governance; and it is argued that these omissions will hinder Koreas’ transition to long term Green Growth. This is further signalled by the lack of community engagement with policy, lack of appropriate indicators to guide green policy (i.e. no carbon footprint measurements) and the need for a bigger than planned shift in investment from consumption of green policy to achieve sustainable Green Growth (as highlighted in Chap. 3). Criticisms and doubts about the longevity and depth of changes aside, it is undeniable that Korea’ Green Growth strategy has achieved remarkable success in the short term, with a sharp reduction in emissions and the development of an impressive range of green technologies in a variety of areas.

In this book we grapple with the task of how to manage the transition from being part of a growth oriented market capitalism model to existing as a model decoupling economic growth from environmental deterioration. It is argued that game-changing Green Growth must be rooted on economic approaches allowing for the inherent complexity of human-environment relationships, and fuelled by policies and managerial techniques promoting synergies – rather than just decoupling – between environment and growth.

A critical, 'deeper' version of Green Growth is also possible, one that is anchored in sustainability science[3] (Chap. 3) and sees 'Greener Growth' just as the start of the journey towards radical change in the design of consumption and production systems. In that sense, 'truly Green Growth' could be to policy what Cradle-to-Cradle is to environmental management (see Chap. 10).

Thus, if economic growth can be described as acceleration in economic activity, critical Green Growth is about rethinking the legitimacy of drivers of growth. Our perceptions of growth's legitimacy are still anchored in the nineteenth century's industrialist narratives: all non-criminal sources of growth are equally legitimate regardless of their impact on the environment or society; growth is quantitative and measured through the production and consumption of physical outputs; sustained growth leads to social welfare and, eventually, reduction of poverty and curbed environmental deterioration.

A key issue that needs attention is the framing of economic progress; moving away from quantity to quality and from the consumption of physical to non-physical outputs (i.e. services, experiences) and from production of environmentally harmful to environmentally enhancing goods and services (Swart et al. 2004). Critical Green Growth should be concerned with the quality and legitimacy of growth and defined as the increase of all economic activity that is not harmful to natural capital. In turn, the quality of Green Growth can be identified by the extent to which 'green' economic activity contributes to enhance and preserve natural capital.

Many of the chapters in this book argued that changes in the economic systems should be about quality of growth (Chaps. 2, 3, 6, and 7). The prevailing Green Growth paradigm advocates a market friendly, 'good'-growth-perpetuating natural capitalism (Luke 2008). In its mildest version it aims for a greener, less resource and carbon intensive economy. In its strongest version it aims for a truly green economy, where resource intensity is minimal since products are constantly reused and renewable energy satisfies the needs of a de-materialised economy.

A second issue of great importance is the indicators that are chosen to monitor the progress of Green Growth. Initial ideas are based on monetary quantification of the value of environmental losses and gains. Thus, economic performance indicators reflect environmental costs by discounting them from GDP. However, giving a monetary value to the natural environment is a challenging task, particularly when we are dealing with irreversible and/or discontinuous alterations in the environment (Held et al. 1999; Stiglitz et al. 2009). In addition, in some countries and sectors, measuring output is about increases in the quality – rather than quantity – of goods produced and consumed, thus making the whole

[3] See Kates et al. (2001) for a discussion of sustainability science, including guiding principles and operative framework.

assessment of GDP dependent on assumptions about the relative value of increases in environmental and non-environmental quality of goods (Stiglitz et al. 2009). Ideally, then Green Growth should be measured by screening the final goods to be included in the calculation of GDP. Green GDP would only capture environmentally neutral goods, where: production processes are low-carbon, non-polluting and had neither depleted non-renewable resources nor had a non-sustainable intensity of use of renewable resources, nor had generated pollutants beyond the carrying capacities of natural systems. A qualitatively weighed measure of GDP would assign more weight to environmentally enhancing goods – those products and services that preserve and develop natural capital – and account for future effects of current investment trends (as the Model in Chap. 6 proposes).

Such screening will require definitions about what threshold should be applied to define low-carbon, what resources are non-renewable, what is 'non-sustainable intensity', and also life-cycle analysis to see whether the end result is an increase in pollution. Measuring Green GDP will require international agreement on standards and disclosure of environmental information along global supply chains (Chap. 7).

Finally, a key challenge to a green economy is how to change the incentives offered to individuals who achieve fulfilment through possession, in order to promote more environmentally friendly outcomes (Torgerson 2001). In this sense, there are other possible trajectories to Green Growth that need to be further investigated. One of them is 'slow consumption' where the focus is on reducing frenetic consumerism, increasing the useful life of products and encouraging personal fulfilment by means other than consumption (Jackson 2010). The other trajectory is a 'green informal economy', the creation of an economic system associated with the enhancement of community that is altogether different from the existing one (Seyfang 2001; Torgerson 2001; Korten 2006) and promotes more concrete and personal types of human interaction than markets and hierarchies.

16.9 Greening of Industrial Studies

This book is part of the Springer Series titled 'Greening of Industry Networks Studies' (GINS). The Series aims to improve our understanding of how shifts in industrial regimes, trade, and technology are creating significant environmental and social impacts and inequities around the world; but also opportunities for sustainable economic growth. The series aims to develop knowledge and transform practice to accelerate a paradigm change toward a sustainable society across disciplines, geography, and sectors. As such, the series will be an integral part of GIN-3D (Greening of Industry Network Third Decade) strategy. The trajectory began a couple decades ago and is still evolving. This and future books will help document this trajectory as well as point it in the appropriate direction.

16.10 Conclusion

This chapter provided an integrative framework to understand current Green Growth policies as the stepping stone in a journey towards truly Green Growth. The framework draws on contributions to the book but also on theories of globalisation, technical innovation, socio-technical transitions and governance. The chapter summarised the book's contributions, emphasising insights and linkages amongst chapters, and finally highlighted gaps and areas for further research. The book aims to help the reader build a quick, evidence-based understanding of Green Growth strategies and challenges to help countries and companies transition towards Green Growth. To this end, the volume provides multiple levels of analysis and focus ranging from broad regional and international to micro-level organisational scopes. Analysis from various disciplines provides for a breadth of approaches useful for addressing Green Growth issues from both practical and theoretical perspectives.

The contrast between and within nations provides further insights into how various regional and cultural boundaries can provide solutions to similar concerns. In turn, the diversity of countries, issues (building environment, energy, transport, climate change) and sectors covered (automotive, textile, oil, chemical, heavy manufacturing, food, construction industry) exemplifies how Green Growth toolkits need to be flexible. It further helps understanding of how tools can be adjusted and tailored to fit a variety of national and local circumstances and stages of development. In many ways, Green Growth is a newborn and this book is an initial attempt to understand how we can nurture and support Green Growth in its evolution.

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