Chapter 12

United We Stand: Regional cooperation from a wider perspective of sustainable consumption and production

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1. Introduction

The importance of international and regional cooperation in promoting sustainable consumption and production (SCP) has been recognised in international policy processes. Article 15 of the Johannesburg Plan of Implementation of the World Summit on Sustainable Development in 2002 calls for international cooperation in line with the principle of common but differentiated responsibilities, and in response to this article, the Marrakech Process was launched in 2003 as an international process, led by the United Nations Environmental Programme (UNEP) and UN Department of Economic and Social Affairs (UN-DESA), for elaborating a draft 10-year framework of programmes on SCP (see Box 12.1).

In the Asia-Pacific region, the Asia Pacific Roundtable for Sustainable Consumption and Production (APRSCP) exemplifies the efforts to foster regional cooperation. Since its establishment in 1997, APRSCP has provided an arena for information sharing and development of partnerships between industry, governments, academia and non-governmental organisations (NGO) in the region to promote SCP. In general terms, it is quite obvious that regional cooperation, such as technical and financial cooperation, is useful to promote SCP.

Chapter Highlights

This chapter aims to demonstrate the potential roles of regional cooperation in promoting SCP in the Asia-Pacific region, from a wider perspective including provision of consumption opportunities for everybody, in particular the poor. Three case studies based on IGES quantitative research are presented to test the key hypothesis of the chapter that SCP requires collective action and coordinated efforts through regional/international cooperation to address potential negative spillover effects and/or to facilitate effective implementation of domestic efforts. The major findings are as follows:

- Seeking win-win solutions through regional and international cooperation is essential to promote SCP in the wider perspective.
- Under economic globalisation and the influence of transboundary environmental pollution, promoting SCP domestically may be neither efficient nor effective when international externalities prevail.
- Production and consumption go hand-in-hand when discussing the issue of SCP and should be regarded systematically as part of the whole.
- Selection of the most appropriate level (e.g., international or national level) is important to address specific SCP issues for effective implementation of cooperation.

Both developed and developing countries should be more open to cooperation and make pragmatic efforts to search for better solutions to address SCP issues.

Box 12.1 Johannesburg Plan of Implementation, Chapter III, Article 15

Encourage and promote the development of a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, delinking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes and reducing resource degradation, pollution and waste. All countries should take action, with developed countries taking the lead, taking into account the development needs and capabilities of developing countries, through mobilization, from all sources, of financial and technical assistance and capacity-building for developing countries. (...)

In addition to these instrumental functions of regional cooperation, a regional/international perspective has fundamental importance for the proper implementation of SCP. With economic globalisation, production and consumption are linked globally through value chains. Consumption in one place can induce environmental impacts in other places and production in one place can influence local residents, neighbouring countries and the global environment. Achieving the objectives of SCP in an individual country may exert unnecessary pressure on other countries in the globalised economy. Furthermore, it must be emphasised that the true objective of SCP is to promote sustainable development by changing the current patterns of consumption and production. Sustainable development must be understood as ensuring that everybody can meet their basic needs without compromising the basis of human survival or at the expense of future generations (see Box 12.2).

Box 12.2 Is sustainable consumption really relevant for developing countries?

Sustainable consumption is frequently misunderstood as a tool primarily aimed at reducing over-consumption in developed countries. The true aim of sustainable consumption is to develop consumption opportunities that would allow everybody to meet their needs, but without generating the associated negative environmental, social and financial impacts, typically seen in developed countries.

Source: UNEP 2005

Along this line, the success or lack thereof of one country's SCP measures should be judged not only on how economic and social development is decoupled from material throughput in that country, but also on how they contribute to sustainable development in other countries. Considering the current rapacious exploitation of global resources by rich countries (as well as the rich in poor countries) mentioned in chapter 1, it would seem that meeting everyone's basic needs is not consistent with the current level of material affluence of rich segments of the world and the gross inequalities along global value chains. As Mahatma Gandhi said "Earth provides enough to satisfy every man's need, but not every man's greed."

Kuhndt et al. (2008) pointed out that industrialised countries expropriated 80% of world total value added at the cost of 20% of world total ecological rucksack.[1] It has been argued that it is possible to distinguish between "needs," which are finite and common across cultures and generations, and "satisfiers of needs," which are potentially infinite and diverse across cultures and generations, and that some satisfiers offer only "pseudosatisfaction" or even violate needs satisfaction (Max-Neef 1991; Jackson and Marks 1999; Jackson 2002). Understanding SCP in this context makes the regional/international perspective involving both developed and developing countries very important, as the key issue is how to connect a reduction and revision in the material consumption of the rich through redesigning the process of needs-satisfaction of the rich, on the one hand, to the needs-satisfaction of the poor by enhancing sustainable consumption opportunities, on the other.

There has been a lack of policy research on SCP issues from a regional perspective. SCP is a cross sectoral issue in nature and quantitative analysis of SCP from a regional perspective usually requires a multi-sectoral and multi-regional analysis which is a challenging task. Nevertheless, filling this research gap is a highly policy relevant and urgently needed task to promote SCP. Without policy research based on quantitative analysis, it may be difficult to identify key priority areas of regional cooperation and to formulate effective policies and strategies to promote SCP, in particular the proposed 10-year framework of programmes on SCP which will be discussed in the 2010-2011 cycle of the UN Commission on Sustainable Development.

The ongoing globalisation of consumption and production further endorses the importance of such research. The volumes of material and energy flows associated with international trades of products and services have significantly increased. This globalised system has yielded rapid economic growth which may have contributed to poverty reduction in several developing countries like China and India, but it has also caused various social and environmental problems as a result of spillover effects and externalities. For example, there is an ongoing debate, particularly in international climate negotiations, over CO_2 emissions embodied in traded commodities. As it is common that the most CO_2 emissions over a product life cycle are associated with the production process, consumption of imported commodities has negative environmental externalities in the country of production. The issue of international spillover effects of domestic climate mitigation through the globalised production system has also drawn wide attention. Without taking into account these contentious issues, the promotion of SCP from the wider perspective is at risk.

Against this background, this chapter presents three case studies that shed light on the potential roles of regional cooperation in promoting SCP in the Asia-Pacific region based on IGES' research work. Each case study has a sufficiently different focus on the issue so as to collectively provide a more complete picture on the role of regional cooperation. The first case study focuses on regional implications of Japanese SCP policies to achieve a low carbon society. This study demonstrates that national SCP policies to address the objectives of an individual country may have negative spillover effects on other countries, while achieving a low carbon society through regional cooperation may provide better well-being for all affected communities in the context of regional sustainable development.

The second case study addresses the issue of emissions embodied in international trade. It presents how embodied emissions act as an indicator for communication through the global value chain to improve the environmental performance of the product supply chain and how regional and international cooperation is important to achieve this end. The third case study highlights the potential of cross-border energy infrastructure development to promote sustainable energy consumption. It demonstrates that regional cooperation can help achieve social, economic and environmental objectives efficiently. Based on these studies, conclusions and policy recommendations are provided to promote SCP in the Asia-Pacific region.

2. Regional cooperation for low carbon society in East Asia

2.1 Low carbon society as a key ingredient of SCP

The concept of a Japanese Low Carbon Society (LCS), which has been reflected in Japanese climate policy including vision statements by Japanese prime ministers (particularly in the Fukuda Vision released in June 2008, as well as the recent statement by Prime Minister Yukio Hatoyama in September 2009), aims at a massive reduction in CO_2 emissions, while satisfying necessary service demands ("2050 Japan Low-Carbon Society" Scenario Team 2007). It requires a drastic reduction of aggregate material throughput, particularly fossil fuels throughput, without compromising the quality of life. While the current prosperity of developed economies is underpinned by mass consumption of fossil fuels, it is now recognised that such an unprecedented scale of fossil fuel use is unsustainable. Fossil fuels are non-renewable resources and they will be depleted at a certain point of time. Moreover, there is accumulating evidence of anthropogenic global warming due to greenhouse gas emissions, and fossil fuel combustion is a major emission source (IPCC 2007). In addition to these physical risks, there are also political risks with the heavy reliance on fossil fuel use, as many fossil fuel abundant regions are, in many cases as a consequence of this abundance, politically sensitive (Lefevre 2007). LCS is thus regarded as a very important ingredient of SCP in Japan and other countries due to the need to move away from a reliance on fossil fuels.[2]

The scenarios to achieve Japan LCS by 2050 (the Japan LCS scenarios) were proposed by a research project funded by the Ministry of the Environment Japan (LCS2050 Project). The Japan LCS scenarios demonstrate the technological potential to reduce Japanese CO_2 emissions by 60-80% from 1990 levels by 2050 ("2050 Japan Low-Carbon Society" Scenario Team 2007). The Japan LCS scenarios are backed by a dozen actions towards LCS that will overcome the currently existing constraints in realising the Japan LCS scenarios. Each of these actions consists of various low carbon measures. For example, the first action "comfortable and green built environment" consists of several measures such as a certificate system and financial schemes to promote low carbon buildings and promote solar and wind utilisation in the design of residences and buildings, which can achieve reductions in the demand for energy per household and per unit area of nonresidential building floor space by 40% from 2000 levels ("2050 Japan Low-Carbon Society" Scenario Team 2008).

This section demonstrates the potential contribution of regional cooperation to SCP based on an IGES study on regional implications of the Japan LCS scenarios. In this study, the baseline Japan LCS scenario without carbon pricing is formulated as a set of the following assumptions:

- Households' electricity demand reduces by 40%, which requires a 20% increase in households' demand of electronics and other manufacturing goods.[3]
- Productivity of energy input for agricultural, manufacturing and service sectors except for the electricity sector increases by 40%, which is achieved by diversion of capital and labour inputs represented by a 20% reduction in productivity of value added inputs.
- Productivity of output augmenting technology for the electricity sector increases by 40%, which is achieved by diversion of capital and labour inputs represented by a 40% reduction in productivity of value added inputs.

Then, two types of carbon pricing to achieve a pre-specified reduction target of Japanese CO_2 emissions (by 25% from the 1990 level) are introduced to the base LCS scenario:

(i) a Japanese domestic carbon tax (LCS-1 scenario) and (ii) a regional cap and trade among ASEAN+3 countries (LCS-2 scenario).[4] The LCS-1 scenario represents the Japanese domestic SCP policy in the narrower sense, in which SCP is only utilised to reduce material throughputs without deteriorating the quality of life in one country, while the LCS-2 scenario represents a regional SCP policy in the wider sense, in which SCP is intended to promote sustainable development in the international context. In order to demonstrate the potential contribution of regional cooperation towards regional SCP in terms of regional CO_2 emission reduction without severe negative economic and social impacts, the allocation of emission quotas under the LCS-2 scenario is assumed to reflect the development level of each member country. In addition, the LCS-2 scenario assumes that financial assistance will flow from Japan to other members (see Box 12.3).

Box 12.3 Emission quota allocation and financial assistance under the LCS-2 scenario

Assumptions for initial emission quota allocation:

- Japan: -25% from 1990 levels (the same target as the domestic carbon tax)
- Republic of Korea: -5% from 2001 levels
- Less developed ASEAN members (Viet Nam, Cambodia, other): +20% from the 2020 business-as-usual (BAU[5]) emissions.
- Remaining ASEAN members: -10% from the 2020 BAU emissions.

Assumptions for financial assistance from Japan:

- To Republic of Korea and Singapore: No assistance
- To China: $1 billion
- To Thailand and Malaysia: $0.3 billion
- To the remaining ASEAN+3 members: $0.6 billion

Source: Authors

2.2 Policy impacts assessment: potential benefits of regional cooperation

The economic and environmental impacts of the LCS scenarios in 2020 were quantitatively assessed by policy simulations using the Regional Environmental Policy Assessment (REPA) model (see Box 12.4).

First the results of the impact assessment of Japan LCS without regional cooperation (LCS-1) are reported. Then the study then examines how regional cooperation reflected in the LCS-2 scenario changes the results.

Box 12.4 REPA model

The REPA model is a multi-regional computable general equilibrium (CGE) model developed to conduct integrated policy impact assessments encompassing environmental, economic and poverty impacts in East Asia (Kojima 2008). The current version of the REPA model employs a 12-region, 33-sector aggregation of the Global Trade Analysis Project (GTAP) database Version 6 (Hertel 1997). The REPA model introduces an environmental module and a policy cost module into the GTAP-E model, a version of the original GTAP model that introduces energy substitution and CO_2 emissions (see Burniaux and Truong 2002).

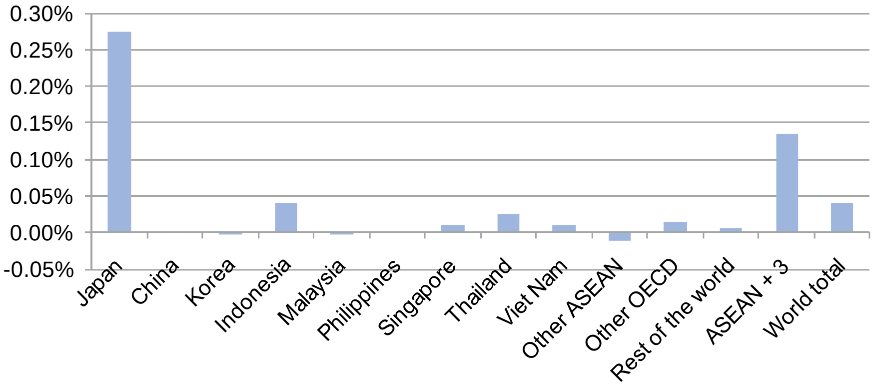
The REPA model employs a recursive dynamic approach to conduct policy impact assessments up to 2020, in which the base datasets corresponding to 2001 are updated by exerting exogenous macroeconomic shocks. In the general equilibrium world where interactions among all sectors in the economy are taken into account, the real costs incurred by implementing environmental policies such as low carbon policies must be measured by loss in social welfare for the same amount of inputs or, the other way around, additional inputs to achieve the same level of social welfare.

The REPA model defines the environmental policy costs for industries as the productivity loss due to diversion of some capital and labour inputs from the production process to abatement activities. This approach can capture the working of environmental policies, but it is necessary to improve parameter estimation related to policy costs based on reliable quantitative data to fully exploit the potential of this approach.

Source: Authors

Figure 12.1 shows the impacts of the LCS-1 scenario on the real gross domestic product (GDP) of each region. Throughout this section the impacts of the LCS scenarios are presented as changes from the business as usual (BAU) results in 2020. It is interesting that the LCS-1 scenario increases Japanese real GDP despite the high rate of carbon tax ($64 per ton of CO_2).[6] The overall direction of economic impacts depends on the balance between productivity gain from energy efficiency improvements and efficiency loss due to both productivity loss caused by abatement activities and price distortion caused by carbon tax. It must be noted that the result could be opposite if the productivity loss caused by abatement activities were more severe than assumed here, which highlights the importance of elaborate cost parameter estimations based on empirical data.

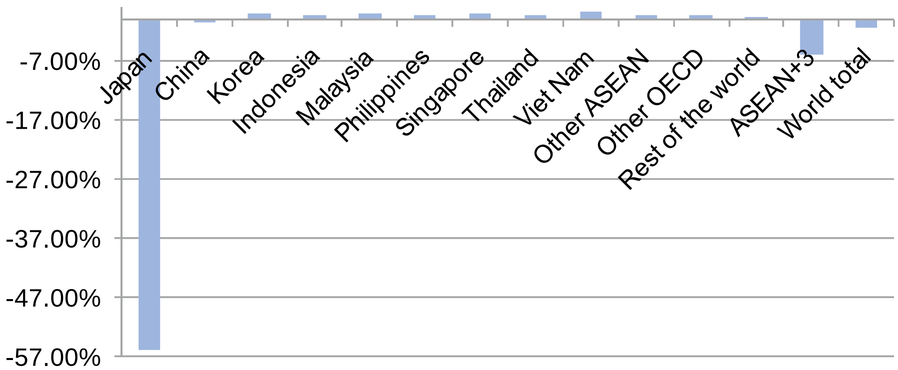
Figure 12.1 Impacts of the LCS-1 scenario on real GDP



Source: REPA simulation results

The results indicate that Japanese measures to achieve LCS without regional cooperation may have negative effects on some countries' economic development. Moreover, there is a fear of spillover effects in terms of increased CO_2 emissions outside Japan, as illustrated in Figure 12.2 in which the CO_2 emissions of each region, except for China, will increase.

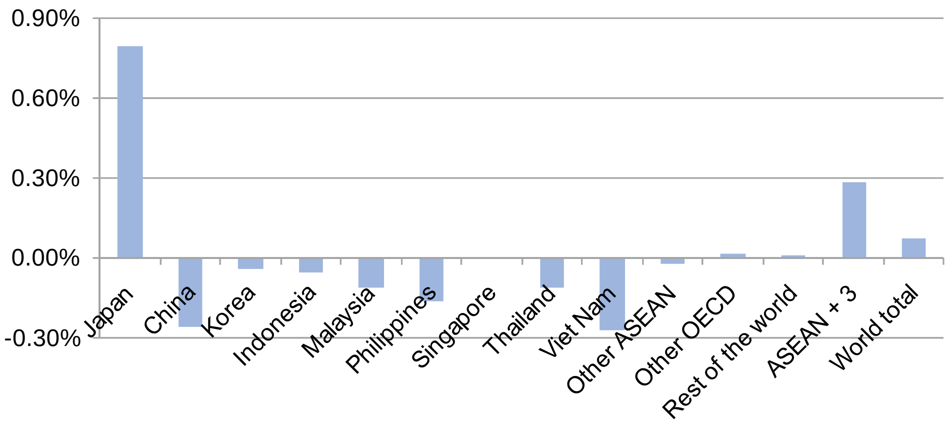
Figure 12.2 Impacts of the LCS-1 scenario on CO_2 emissions



Source: REPA simulation results

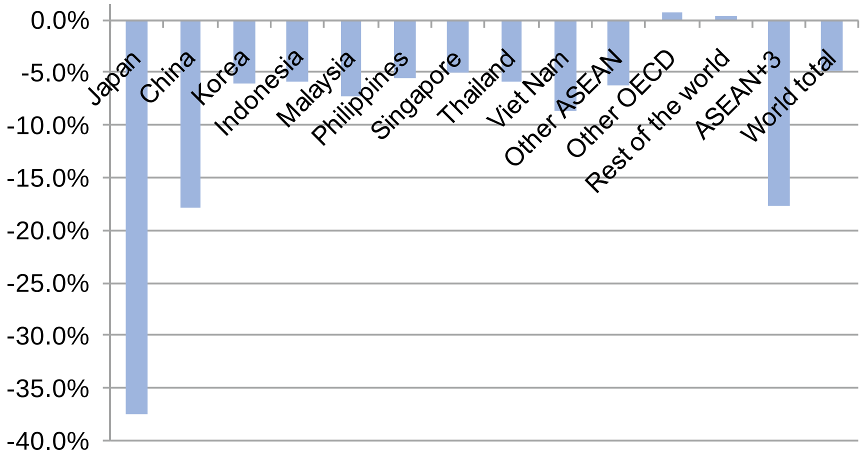
These results indicate that the LCS-1 scenario contributes to Japanese economic development with a drastic reduction of national CO_2 emissions,[7] but it may have adverse environmental and economic effects on some other countries. In this sense, Japanese domestic measures towards LCS without regional cooperation may not promote SCP in the true meaning. The impact assessment of the LCS-2 scenario tells a different story. Figures 12.3 and 12.4 collectively demonstrate that regional cooperation in terms of the regional cap and trade and the financial assistance from Japan to other members of the cap and trade scheme will achieve a significant carbon emissions reduction of the overall ASEAN+3 (by 17.6% from the BAU emissions in 2020) with relatively insignificant real GDP losses.

Figure 12.3 Impacts of the LCS-2 scenario on real GDP



Source: REPA simulation results

Figure 12.4 Impacts of the LCS-2 scenario on CO_2 emissions



Source: REPA simulation results

Except for Japan, which enjoys a much lower carbon price ($4.4 per ton of CO_2 instead of $64.0 per ton of CO_2 under LCS-1), introduction of a carbon price to all other ASEAN+3 countries will suppress their real GDP regardless of financial assistance. Still, it seems possible to find win-win solutions for all member countries by increasing the amount of financial assistance from Japan.[8] Indeed, the regional real GDP of ASEAN+3 will increase by around 0.3%. Moreover, it must be noted that this model does not take into account regional cooperation in other forms, in particular technical assistance to improve energy efficiency in developing countries, which is expected to have significant positive economic impacts.

2.3 Policy implications

The main message from this study is that pursuing SCP in a narrower sense, in which the problem is addressed through the drastic reduction of aggregate material throughput without compromising the quality of life in one country, may adversely affect other countries. Regional cooperation could play an important role to overcome this problem and to achieve SCP in a wider sense, that is, promotion of sustainable development worldwide by changing the patterns of consumption and production. Based on quantitative policy impact assessments using a CGE model, the study provides supportive evidence of this message.

The analysis also illustrates the potential worldwide benefits of regional cooperation. Table 12.1 shows the impacts of the LCS scenarios on real GDP and CO_2 emissions in terms of changes from the BAU scenario.

Table 12.1 Impacts of LCS scenarios in terms of changes from BAU scenario

	Real GDP		CO_2 emissions	
	(million $)	%	(million tonnes)	%
LCS1-scenario	19,660	0.04	-742	-1.41
LCS2-scenario	36,612	0.07	-2,525	-4.81
Difference	16,952		-1,783	

Source: REPA simulation results

According to these results, regional cooperation under the LCS-2 scenario increases global real GDP by around $17 billion while it reduces CO_2 emissions by 1,783 million tonnes, compared with the LCS-1 scenario in which only Japan pursues low carbon society through domestic measures.

In the Asia-Pacific region there are several platforms for regional cooperation such as the East Asia Summit (EAS), the Association of Southeast Asian Nations (ASEAN), the South Asian Association for Regional Cooperation (SAARC) and the Greater Mekong Subregion (GMS), among others. To implement regional cooperation for achieving SCP in a wider sense, it would be effective to connect the political initiatives of developed countries (e.g., Prime Minister Hatoyama's initiative that commits public financial assistance and technology transfer to developing countries) to these regional cooperation platforms, thus demonstrating the mutual benefits of such cooperation.

3. Embodied emissions as an effective indicator to communicate the importance of the global value chain

To achieve SCP it is necessary to take into account all of the impacts (environmental, economic and social) that a product or service has throughout its life cycle, "from cradle to grave." Products may have totally different environmental impacts during different stages of their life cycle from extraction of raw materials, product manufacturing, packaging and distribution, product consumption, recycling, and waste management, until end of life. An environmental improvement made by a manufacturer within its factory border cannot sufficiently ensure that the products will have a good environmental performance throughout its life cycle.

The designers of the products, the upstream suppliers, the retailers, the downstream consumers and waste managers all play a role in influencing the total impacts induced by a product. It is therefore important to communicate among all stakeholders in a product supply chain to achieve effective improvement through life-cycle management.

With international trade and economic globalisation, the value chain[9] of a product becomes increasingly complex and involves worldwide geographic locations. Decoupling of economic growth from resource use and greenhouse gas (GHG) emissions that have been achieved in the developed world could shift pollution to the developing world, particular in Asia, through outsourcing and offshore activities of companies (Kuhndt et al. 2008). To achieve global governance of resource use and climate change, dematerialisation and decarbonisation throughout the global value chain are important and require cross-border cooperation among key stakeholders in the chain.

In this section, "embodied emissions" (see Box 12.5) are demonstrated to work as an effective indicator to communicate the outcomes of the global value chain. Identifying the methods of applying this approach to address environmental "hot spots" effectively through bilateral, regional and international cooperation is recommended.

Box 12.5 Embodied emissions

Embodied emissions refer to CO_2 emitted from each upstream stage (production) of the supply chains of a product, which is used by the downstream stage (consumption). Closely related to life-cycle thinking and the global value chain, it helps present the total emissions released into the atmosphere and the geographic locations where the emissions are being released and indicates the resulting environmental "hot spots," the most carbon-intensive stages and locations of the global value chain.

Source: Authors

3.1 Accounting for emissions embodied in international trade

Many academic works calculate embodied emissions to address consumption in developed countries. For Japan, the territorial CO_2 emissions are estimated to have been 1,115 megatonnes of CO_2 (Mt-CO_2) in 1990,[10] while carbon embodiments in the imports to Japan are 249 Mt-CO_2, surpassing emissions embodied in Japan's exports (170 Mt-CO_2) (Kondo and Moriguchi 1998). For Denmark, the CO_2 trade balance changed from a surplus of 0.5 Mt in 1987 to a deficit of 7.0 Mt in 1994 (Munksgaard and Pedersen 2001). Norwegian household consumption-induced CO_2 emitted in foreign countries represented 61% of its total indirect CO_2 emissions in 2000 (Peters and Hertwich 2006). For the U.S., the overall CO_2 embodied in U.S. imports grew from a range of 500 to 800 Mt-CO_2 in 1997 to a range of 800 to 1,800 Mt-CO_2 in 2004, representing 9 to 14% and 13 to 30% of U.S. national emissions in 1997 and 2004, respectively (Webber and Mattews 2007).

At the multi-region level, about 13% of the total carbon emissions of six Organisation for Economic Co-operation and Development (OECD) countries (Canada, France, Germany, Japan, UK and U.S.) were embodied in their manufactured imports in the mid-1980s (Wyckoff and Roop 1994). More recent research (Peters and Hertwich 2008) shows that around 5,000 Mt of 42,000 Mt CO_2 equivalent of global GHG emissions in 2000 were embodied in the international trade of goods and services, most of which are imported by developed countries from developing countries.

These studies indicate a significant amount of carbon embodied in international trade and show that developed countries are "exporting" carbon emissions, mostly to developing countries. An important message derived is that because of carbon leakage, the achievement of mitigation targets by developed nations alone cannot be completely effective in constraining global emissions. Effective total emission control over the global value chain of a product can help address the carbon leakage issue.

IGES conducted a study on CO_2 emissions embodied in international trade in the Asia-Pacific (Zhou 2009). The study applied the Multi-region Input-Output (MRIO) model[11] to account for embodied emissions for ten selected economies, including three OECD countries (Japan, Republic of Korea and U.S.), five ASEAN countries (Indonesia, Malaysia, Philippines, Singapore and Thailand), China's mainland and Taiwan. An input-output model is widely used to present inter-sectoral relations and analyse economy-wise influences driven by consumption. It has been extensively used for environmental analysis since the 1980s, in particular in the areas of accounting for energy consumption, and carbon emissions and ecological footprints embodied in household consumption.

A MRIO model provides detailed accounts for imports (with the identification of the source industry and the country of origin) and exports (with the identification of the destination industry and its geographical location). It is therefore useful to analyse the impacts related to international trade. Using the Asian Input-Output Table 2000 (AIO 2000) (IDE-JETRO 2006) for 24 sectors in the ten economies, the study calculated the total emissions embodied in each final product and traced the contribution of each stage of the global value chain of a product to the total emissions induced by the product.

AIO 2000 includes 24 aggregated sectors for each country. Each sector produces one composite final product and requires intermediate inputs from other sectors. Sectors (including transportation and the service sector) in different countries interact with one another and form the global supply chain of products. It should be noted that different degrees of sector aggregation in an input-output model can influence the calculation results (Lenzen et al. 2004).

Table 12.2 presents CO_2 emissions embodied in the final consumption of each country. By row, for example, Indonesia "imported" 0.8 Mt-CO_2 from Malaysia, 0.2 Mt-CO_2 from the Philippines, and so on. By column, for example, Indonesia "exported" 0.3 Mt-CO_2 to Malaysia, 0.1 Mt-CO_2 to Singapore, and so on. For trade balance in terms of embodied emissions, for example, Indonesia has a net import of 0.5 Mt-CO_2 (calculated by 0.8-0.3) from Malaysia. The trade balance of embodied emissions shown in the last row is calculated by the row sum minus the column sum for each country. Positive values indicate "net imports" of emissions and negative values indicate the "net exports." China is the biggest net importer of embodied emissions (with a net import of 452 Mt-CO_2), while the U.S. is the biggest net exporter of emissions (with a net export of 464 Mt-CO_2), followed by Japan.

Table 12.2 CO_2 emissions embodied in international trade in 2000*

Region	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA	ROW
IDN	133.2	0.8	0.2	0.6	0.4	0.2	0.6	0.4	2.6	6.4	32.4
MYS	0.3	47.2	0.3	1.8	0.6	0.5	0.9	0.4	3.5	6.7	27.8
PHL	0.0	0.1	36.5	0.0	0.1	0.1	0.1	0.1	1.5	4.1	9.3
SGP	0.1	0.8	0.3	35.7	0.3	0.3	0.4	0.3	1.1	2.9	25.6
THA	0.3	0.5	0.2	0.5	91.8	0.3	0.4	0.2	3.1	5.3	31.3
CHN	1.3	2.0	0.4	1.9	2.0	2,252.2	3.6	4.8	51.6	103.6	369.1
TWN	0.3	0.5	0.3	0.2	0.4	2.1	94.4	0.4	3.1	8.3	50.2
ROK	0.3	0.3	0.3	0.3	0.2	1.4	1.0	267.5	4.0	9.8	77.1
JPN	0.5	1.0	0.4	0.8	0.9	1.7	2.6	1.6	861.9	15.4	55.2
U.S.	0.4	1.0	0.5	0.9	0.8	2.3	4.1	2.6	11.3	4,318.5	333.8
ROW	25.0	19.0	11.0	38.0	25.0	79.0	46.0	76.0	189.0	659.0	
Trade balance of embodied emissions	16.0	17.0	1.0	-13.0	11.0	452.0	6.0	8.0	-191.0	-464.0	

Note: IDN: Indonesia; MYS: Malaysia; PHL: the Philippines; SGP: Singapore; THA: Thailand; CHN: China's mainland; TWN: Taiwan; KOR: Republic of Korea; JPN: Japan; U.S.: United States of America; ROW: the rest of the world.

* Emissions are measured in million tonne of CO_2.

Source: Zhou (2009)

Table 12.3 presents the carbon intensity (in terms of CO_2 per unit of product value) of selected carbon-intensive products made from different countries. For example, the number in row 2 column 2 shows that the carbon intensity of fishery products produced from Indonesia is 1.3 kg-CO_2/$. For each product category, the top three carbon-intensive products identified by their countries of origin are highlighted in shaded colour.

For example, the crude petroleum and natural gas produced from Singapore, the Philippines and China, respectively, are more carbon-intensive than similar products produced from other countries, in particular those produced from Malaysia and Japan. On the one hand, most of the products made from China or from Indonesia are marked as more carbon-intensive than similar products made from other countries. However, the carbon-intensity of most of the products made in Japan is much lower than in other countries. Because of the large differences in the carbon-intensity of similar products, providing such information on products is therefore effective to help consumers take into account environmental considerations when they make purchasing decisions.

Table 12.3 Carbon intensities of selected carbon-intensive products

Products	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	U.S.
Fishery products	1.3	1.2	0.7	1.3	2.0	1.4	0.2	3.7	1.5	1.0
Crude petroleum and natural gas	2.0	0.1	13.9	20.4	0.1	3.5	2.9	0.6	0.1	1.0
Chemical products	1.6	1.0	0.7	0.8	1.3	3.9	0.8	0.7	0.2	0.7
Petroleum and petro products	3.0	4.5	0.2	0.4	0.2	2.4	0.2	0.2	0.1	1.3
Non-metallic mineral products	7.3	1.8	2.1	0.9	2.0	4.7	1.2	1.3	0.6	1.1
Metal products	2.5	1.0	0.8	0.7	1.0	4.7	1.2	0.6	0.4	0.6
Trade and transport	11.8	6.6	3.2	22.1	6.6	20.9	3.0	2.2	0.8	7.5
Electricity, gas and water	2.0	1.4	1.6	0.3	1.2	1.9	0.9	1.6	0.4	0.6

Note: For different product categories, shaded entries in each row indicate top three carbon-intensive products identified by their country of origin. Carbon intensities are measured in kg-CO_2/$ at 2000 value.

Source: Author's estimation

From the perspective of global value chain management, the MRIO analysis was applied to trace the contribution of each upstream stage to the total emissions induced by the production and consumption of a product. For example, the total carbon intensity of non-metallic mineral products (e.g., cement) originating from China is 4.7 kg-CO_2 per dollar of production, of which 63% (3.0 kg-CO_2) is attributable to the energy consumption required to fulfil the production, 26% (1.2 kg-CO_2) is attributable to the manufacturing process and 1% (0.5 kg-CO_2) is attributable to other stages (including stages located in other countries) in the value chain.

This information helps identify the most carbon-intensive stages and their geographical locations. Allocating limited resources to address these carbon-intensive "hot spots" through investments in abatement and technology advancement can achieve effective reduction and thereby improve the overall environmental performance of a product. As the value chain of a product links producers and consumers located in different countries, bilateral and regional cooperation in technology transfer and financial support, in particular from industrialised countries to developing countries, are therefore important.

3.2 Applications of embodied emissions

As presented in the case study for ten economies in the Asia-Pacific region, embodied emissions can be used as an effective indicator of communication among different stakeholders in the global value chain of a product from the upstream production to the downstream consumption. Several applications may be recommended to achieve SCP in a cost-effective way through bilateral, regional and international cooperation.

First, many environmental problems are attributable to international trade directly or indirectly because environmental costs are not internalised, especially in developing countries where environmental requirements are usually low. Setting a global uniform carbon price on emissions embodied in tradable goods can help internalise carbon costs which will be taken up by the final consumers (For reference prices from current carbon trading markets, please see Capoor and Ambrosi (2008)). By doing so, good environmental performance will become a new gradient of international competitiveness in addition to traditional factors, such as technology advancement and low costs of labour and resources, for example. Setting a uniform and equitable carbon price equivalency, however, requires bilateral, regional and international cooperation and special considerations of lower income citizens who are generally disadvantaged since their consumption bundle comprises a higher percentage of emissions-intensive commodities (Casler and Rafifui 1993; Common 1985; Cornwell and Creedy 1995 a, b; Hamond et al. 1999; Herendeen and Fazel 1984; Roberts 2008; Smith 1992; Speck 1999).

Second, with the knowledge on carbon-intensive “hot spots,” major stakeholders or countries in the value chain can work together to mitigate emissions effectively through financial and technological cooperation. Compared to the financial support mechanisms and technological cooperation under the United Nations Framework Convention on Climate Change (UNFCCC), cross-border cooperation among stakeholders in the global value chain is more possible to establish because they are pursuing common benefits from the global value chain. When industrialised countries are downstream consumers and developing countries are upstream producers, industrialised countries can invest in or transfer technology to the “hot spot” production stages in developing countries.

Third, embodied carbon as an indicator has been applied by the corporate social responsibility system and eco-labelling schemes implemented in both developed and developing countries. However, the standardisation of calculation and its practice requires regional and international cooperation.

Fourth, consumption-based accounting systems for national inventories are already becoming popular for dealing with issues such as “carbon leakage” (Tuncer and Schroeder 2009). However the most feasible application is still being debated and data for accounting are not always available. Proper discussion of this issue at UNFCCC and the cooperation between the UNFCCC and the World Trade Organization (WTO) are imperative to address the connections between climate change and international trade.

4. Cross border energy infrastructure development for sustainable energy use

4.1 Efficiency improvement in terms of electricity production in Asia

It is a paradox of growth that many resource rich countries are suffering from poverty and lack basic needs in contrast to the luxury and affluent lifestyles in comparatively resource poor but economically developed countries. The apparent curse of natural resources is a well documented phenomenon. Several researchers like Gylfason (2001), Sala-I-Martin (1997) and others have found a negative correlation between natural resource abundance and economic growth. Kronenberg (2003) further argued that the curse of natural resources is also true in transitional economies facing increasing demand for primary goods in the domestic market. For example, while a very large amount of the resources available in the world are in the Asian region, the most energy consuming regions are North America and European countries as well as Japan. In spite of vast energy resources in hand, the majority of the Asian developing regions suffer from a lack of electricity supply. Disparity and asymmetric distribution of consumption of electricity, one of the primary needs of modern society, among the countries and regions across the world are very pronounced in Asia.

This region also has a very high dependency on energy for its economic growth measured in terms of GDP-Energy elasticity (1.23%),[12] which is twice as high as the world average (Wu 2005). High population growth, especially in India and the Southeast Asian countries, is an additional hurdle in meeting burgeoning energy demands. Reeling under these three major growth impediments, the Asia-Pacific region needs to efficiently and effectively utilise resources to ensure uninterrupted development. According to the International Energy Agency (IEA), Asia is now at the top of the list in terms of annual energy demand increases with 3% annual growth rate of primary energy demand to sustain the current level of economic development (IEA 2008).

The electricity sector itself will consume around 20% of the total primary energy supply in the world by 2015 and around 30% in the Asian region. This means that one third of the total primary energy demand in Asia will be for electricity generation. Being the single largest energy sector of the economy, the electricity sector needs to deal with issues such as lowering the GDP-Energy elasticity for better energy security, helping to reduce poverty by energising more than 300 million people in the region who are excluded from modern electricity supply, and protecting the global environment by restricting the emissions of GHGs and air pollutants through cleaner and greener technologies.

4.2 Mapping of regional electricity demand and supply

By 2030, the Asian region will consume more than 37% of the total global electricity, which would be mainly generated from coal fired power plants (IEA 2008). There will be around 6% efficiency improvement in the coal fired power generation technology from 31% to 37% over the next two decades, though the improved level will be still lower than the OECD's average efficiency level of 41%. These projections indicate a huge amount of resource consumption by this region for power generation. IEA's World Energy Outlook (IEA 2008) further predicted that the majority of the power in this region will be generated through conventional coal fired power plants mainly because of low production costs.

The reasons for low cost can be further attributed to various factors like abundance of coal resources in the region and its relatively low cost of extraction, cheap proven technologies and no binding commitment for emissions reduction especially under the Kyoto Protocol (except Japan). Due to various geopolitical and investment uncertainties, natural gas and oil resources may not be fully exploited compared to coal (IEA 2008). China and India will produce cheap steam coal for power generation not only to meet their domestic demands but also for exporting; many countries in this region will remain dependent on imported coal despite their rich natural gas and oil resources. This can affect the region's electricity market in two ways. First, it restricts the use of comparatively cleaner fossil fuel like natural gas. Second, it increases the international coal price which further impacts on the profitability of the power companies.

Thus, it is very important to address geopolitical and investment uncertainties against geographically distorted resource availability for countries to achieve the required level of efficiency and effectiveness in electricity generation and supply. Table 12.4 shows the distribution of energy resources (proven reserves) across the Asian region compared to their respective electricity demand growth rates.

Table 12.4 Proven reserves of energy resources in Asia

Sub Region	Coal (billion tonnes)	Oil (million tonnes)	Natural Gas (billion cubic meter)	Hydro Power (giga watt)	Electricity demand growth
South Asia	212	913	2,828	215	5-6%
East Asia	64	1,628	6,520	409	14-16%
West & Central Asia	46	22,278	33,367	128	2-3%

Note: South Asia sub region includes: Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka
East Asia sub region includes: ASEAN countries, plus China
West & Central Asia includes: Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Kyrgyz Republic and Iran

Source: Bhattacharya and Kojima (2008)

Though West and Central Asia record the lowest electricity demand growth rates in the region, they are endowed with plenty of natural resources along with mothballed infrastructure for power generation which was started under the Soviet Union regime but could not be completed. Those incomplete power plants and abandoned natural resources are now surplus resources for the sub-region after the break-up of the Soviet Union in 1999. With the current economic condition of the sub-region and its future prospects to 2030, it has been estimated that this region would be able to supply more than 11 tera watt hour (Twh)[13] of power every year to the rest of Asia by operating existing power plants at full capacity without additional investment. Similarly, some countries of the Greater Mekong Subregion (GMS) in the eastern part of ASEAN are endowed with massive hydropower potential along with natural gas which is so far untapped and is surplus to this subregion's economic growth prospect.

4.3 Sustainable consumption of electricity in the context of the Asian economy

It has been estimated that the current level of energy reserve resources could be sufficient to fuel Asian economic growth provided an efficient and effective utilisation of these resources is achieved through regional cooperation. Single country stand-alone efforts may not be sufficient to allow for a stable and reliable electricity market in the coming years foreseeing the trends of various major influencing factors, including fuel supply. Traditionally, national power development plans recommend setting up new power plants to satisfy future demand. These plans normally get built on relatively certain domestic fuel supply predictions and uncertain international procurement plans to diversify fuel supply sources. Nevertheless, external and internal factors constrain the power plants' efficiency due to extreme uncertainty in the global energy supply market which is often beyond a country's control. International terrorism, oil tanker piracy, exporting countries' domestic policy changes, natural disasters and even seasonal fluctuation of river water flow (mainly for hydropower) are some examples which can seriously jeopardise the energy procurement plans of importing countries.

Impacts of such uncertainties can be further observed through the decreasing reserve margins[14] of importing countries' national electricity markets across the Asian region (APERC 2001) which endangers the energy security situation. It further compels countries to adopt more expensive financial risk hedging mechanisms to protect their fuel and resource supply for a longer period (over 15 to 20 years). Sometimes the costs of such risk mitigation measures can reach 50% of the total cost of production and can plunge the entire market into deep uncertainty. It has also been estimated that cross border electricity grids can reduce an individual country's reserve margin requirement by around 5% (APERC 2001) which can save a significant amount of resource utilisation.

Greenfield power projects,[15] which are now mushrooming all across this region in the name of meeting the future demand for electricity, are not only consuming all sorts of additional resources including land, water, energy and capital during the commissioning of the plants but also restricting alternative utilisation of these resources for other developmental needs far into the future. If a greenfield project can be avoided with an alternative route to meet future demand, then the saved resources can be utilised for other urgent and developmental purposes like agricultural production and social infrastructure development or for more environmentally benign power production. Full load operation of existing plants ensures full scale utilisation of the infrastructure, higher economy of scale and better system efficiency which could all help to avoid greenfield power projects and reduce the average costs of electricity production and subsequent tariff reduction.

It will be effective to have a flexible resource utilisation policy, instead of resource locking policy, to fuel Asian development in a sustainable manner.

In this context, revitalising outdated power infrastructure built under the Soviet Union regime, re-energising undersupplied power plants and conducting systematic renovation and modernisation (R&M) of the older plants to increase the heat rate[16] can be very effective. Moving one step further, cross border grid linkages can also help to manage the load of a particular country through power trading, using the time difference in peak and off-peak power demands in different countries. For example, India can import power during its evening peak times from Thailand which is 1.5 hours ahead and during their own off-peak zone during that time. This type of cross border electricity load management is quite reasonable and efficient in terms of resource utilisation. Therefore, it will be effective to have a flexible resource utilisation policy, instead of a resource locking policy, to fuel Asian development in a sustainable manner. Sustainability ensures economic growth along with social and environmental protection and stability. Cross border electricity trading can ensure all these outcomes for Asia by providing efficient selection of the location of new power plants (if required), by efficient designing of the power plant based on domestic as well as cross border demand so that plants can operate at full load capacity from the beginning, and by efficient selection of technology and fuel sources to become cost competitive.

It is estimated that the total potential of cross border electricity trading possible within the Asian region is around 200 Twh per year, which otherwise needs to be generated from dirtier fossil fuels like coal. Table 12.5 shows the potential cross border power projects in Asia with detailed information on sources and capacity of transmission. This table shows that around 300,000 MW of hydropower can be promoted purely for cross border power trading purposes where the proposed ASEAN grid interconnection could play a major role. Least developed countries like Lao PDR and Bhutan, blessed with an abundance of hydropower potential, can really make the difference in the regional electricity availability scenario.

Table 12.5 Potential cross border power projects in Asia

Sub Region	Total Installed Capacity (MW)	Maximum Power Transmission (Twh/y)
South Asia (SA)	**11,934**	**58.2**
	- Hydro: 8934 (75)	- Hydro: 36.4
	- NG: 1500 (12.5)	- NG: 10
	- Grid Interconnection: 1500 (12.5)	- Grid interconnection: 11.8
East Asia (EA)	**20,825**	**102.0**
	- Hydro: 13,625 (65)	- Hydro: 47
	- Grid Interconnection: 7200 (35)	- Grid Interconnection: 55
West and Central Asia (WCA)	**9,700**	**40.4**
	- Hydro: 7,300 (75)	- Hydro: 23.6
	- NG/Thermal: 1000 (10)	- Thermal: 6
	- Grid Interconnection: 1400 (15)	- Grid interconnection: 10.8
Total	**42,459**	**200.6**
	- Hydro: 29,859 (70)	- Hydro: 107
	- NG/Thermal: 2,500 (6)	- NG/Thermal: 16
	- Grid Interconnection: 10,100 (24)	- Grid interconnection: 77.6

Note: Figures inside the parenthesis is the % to total capacity in bold.

Source: Bhattacharya and Kojima (2008)

4.4 Impacts of cross border electricity projects

In the context of orienting the electricity sector towards SCP, cross border energy infrastructure projects play a vital role. From the sustainable consumption point of view, it encourages efficient utilisation of natural resources for power generation by reducing unnecessary greenfield power projects, by improving the plant load factor of existing plants, and also by enhancing the efficiency of older plants through regular and systematic R&M activities required for maintaining the grid supply code.[17] By ensuring these measures, cross border power projects actually optimise the resource consumption for power production and make potentially locked-in resources available for other uses. From the sustainable production point of view, such projects address three main concerns for narrowing the development gap within the region, discussed at the beginning of this section. Sustainable production of electricity actually reduces the GDP-energy elasticity for the region through efficiency improvement and helps to achieve a better level of energy security. It further strengthens the financial sustainability of companies as well as governments. It has been estimated that the regional net monetary benefits of such cross border power projects, which can actually create a multiplier effect in the economy, can be around $3.5 billion per year with maximum benefits to the East Asian subregion (Bhattacharya and Kojima 2008).

Moreover, cross border energy infrastructure projects may create net positive impacts on the environment by reducing atmospheric emissions due to efficient and effective production mechanisms. Note, however, that the social and ecological impacts of large hydropower projects can reduce the net benefits. Table 12.6 shows how these cross border projects can affect the five major environmental indicators in this region. Major benefits come from reduced GHG emissions and local health impacts due to inter-fuel substitution (coal versus hydropower) and grid interconnection. Therefore, such projects can also work as mitigation activities in the context of combating climate change. The most heavily advantaged subregion is East Asia, including China.

Table 12.6 Environmental impacts of cross border energy project

Impacts	Sub Region : SA		Sub Region : EA		Sub Region : WCA	
	Coal-Hydro (net benefit)	Grid Interconnection (net benefits)	Coal-Hydro (net benefit)	Grid Interconnection (net benefits)	Coal-Hydro (net benefit)	Grid Interconnection (net benefits)
Health effect	221.31	71.74	285.76	334.40	143.49	65.66
Crop loss	-8.85	-2.87	-11.43	-13.38	-5.74	-2.63
Material damage	5.62	1.82	7.26	8.49	3.64	1.67
Acidification	58.24	18.88	75.20	88.00	37.76	17.28
Global warming	457.18	148.21	590.32	690.80	296.42	135.65
Total	733.50	237.78	947.11	1108.32	475.57	217.63

Note: SA: South Asia; EA: East Asia; WCA: West and Central Asia. All the figures are in $ million at year 2000 constant value.

Source: Estimated by the authors using basic data from Voss (2000)

A case study on the impacts of investment in cross border power projects between China and Thailand further corroborates the importance of such projects in the context of SCP of the electricity sector of this region. According to the case study, the China-Thailand cross border power projects investment will ensure unaffected economic growth in terms of GDP along with increasing employment (which contributes to poverty reduction) and reduced emissions (which contributes to protecting the environment). Table 12.7 shows that the Jinghong-Nuozhadu hydropower project, the largest energy project in the Lancang-Mekong basin, is expected to boost the GDP of Thailand and China by 3.45% and 1.15%, respectively, by increasing electricity supplies to Thailand and China by 47% and 12%, respectively, by 2020. It also shows that this project would reduce CO_2 emissions from the two countries by 1 million tonnes per annum respectively.

Table 12.7 Impacts on China and Thailand from cross border energy project

	GDP ($ million)	Labour payment ($ million)		SOx (thousand tonnes)	CO_2 (million tonnes)
		Skilled	Unskilled		
China	75.9	3.7	-13.8	0.9	-1.0
Thailand	45.7	-1.0	-6.1	-0.2	-0.9

Source: Bhattacharya and Kojima (2008)

In summary, cross border energy projects, especially electricity generation and transmission projects, can bring overall benefits to regional SCP by improving the economic, environmental and social well being of the people. On the one hand, such projects optimise the utilisation of exhaustible natural resources for electricity production, which promotes sustainable production of electricity and on the other hand, promotes sustainable consumption of resources for human utilisation. Consequently, such projects can help national governments to promote sustainable development.

Nevertheless, cross border energy projects have their own inherent risks due to uncertain negative external influences. Sudden changes in bilateral relations between the countries (such as between Thailand and Cambodia, or India and Bangladesh, for example) or even sudden insurgencies created by militant activities across the border can disrupt the supply of power. Even changes in domestic power policies of importing countries can also negatively influence the viability of such projects. Amidst the growing geo-political instability of this region, cross border energy projects might require additional expenses for physical protection and risk covering insurance premiums which are not considered in this current analysis. It is therefore prudent to consider such risks while planning for such projects.

5. Conclusions

This chapter emphasises the importance of regional perspectives to promote SCP, and demonstrates, based on quantitative case studies conducted by IGES, that SCP requires collective action and coordinated efforts through regional and international cooperation to address potential negative spillover effects and/or to facilitate effective implementation of domestic efforts. The key messages extracted from the three case studies are as follows.

First, seeking win-win solutions through regional and international cooperation is essential to promote SCP in the true meaning, that is, to provide consumption opportunities that would allow everybody to meet their needs without exceeding environmental carrying capacity (UNEP 2005). In the worst case, one country's efforts to promote SCP in that country could have adverse effects on SCP in this sense. The first case study shows that Japanese efforts to achieve a low-carbon society by domestic measures alone may have adverse economic and environmental impacts in terms of increased CO_2 emissions for other countries, while the introduction of regional cooperation may enable the region to reduce CO_2 emissions collectively with relatively insignificant real GDP loss. The third case study demonstrates, with an example of regional energy infrastructure development, that regional cooperation could bring about win-win solutions including economic development, poverty alleviation and environmental improvement. The poverty alleviation aspect of SCP must be taken into account, especially for developing countries where poverty is still the first priority to achieve sustainable development.

Second, with economic globalisation and the influence of transboundary environmental pollution, promoting SCP domestically may be neither efficient nor effective in some cases, given the context and conditions present. The first case study provides some supportive evidence that the introduction of regional cooperation may improve effectiveness and efficiency of Japanese LCS measures. The second case study demonstrates that decoupling resource use and emissions from domestic economic growth and shifting the "hidden impacts" to other countries, especially to countries with lower environmental requirements or lower technologies through outsourcing and off-shoring activities, were also not effective in achieving dematerialisation and decarbonisation at the global level. Collective action is required.

Third, production and consumption are paired in the SCP domain and should be considered in a systematic way. The second case study points out the necessity to take into account both the upstream (production) and the downstream (consumption) sides in order to reduce the total emissions embodied in the global value chain.

Fourth, it is important to select the appropriate level, e.g., international level, regional level, bilateral level, or product level, to address specific SCP issues for effective implementation of cooperation. For example, implementing a cap and trade scheme for carbon at the global level might not be efficient due to high transaction costs but could be efficient at the regional or bilateral levels. Similarly, while North-South technology transfer at the global level has entailed many difficulties, a small number of stakeholders who face the same economic benefits and environmental costs involved in the value chain of a product could make collective efforts through investment or technology transfer to solve the issues surrounding the region's "hot spots."

Finally, both the developed and developing world should be more open to cooperation and make pragmatic efforts to search for better solutions.

The future research agenda includes the need to improve the reliability of data through field surveys and an elaboration of analytical tools and technology specifications. It may also be useful to connect quantitative policy impact assessments with political science analysis to address implementation feasibility issues. With these improvements, quantitative policy impact assessments will greatly contribute to implementing regional cooperation towards SCP by demonstrating potential benefits in a tangible manner.

Notes

1. Ecological rucksack, or material intensity per unit of service (MIPS), is the total quantity of the natural material exploited for the whole life cycle of a product from its generation to its disposal.
2. For the potential contribution of LCS to SCP from the energy security perspective, see Kojima (2010).
3. It assumes that households need to buy more energy efficient equipment.
4. ASEAN +3 consists of 10 Association of Southeast Asian Nations (ASEAN) countries (i.e., Brunei Darussalam, Cambodia, Indonesia, Lao P.D.R., Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam), Japan, China and the Republic of Korea.
5. BAU corresponds to situations when no actions consisting of the LCS scenarios are taken.
6. In this study, the collected carbon tax is transferred to households in a lump sum.
7. Indeed, a 30% reduction from the 1990 level corresponds to almost a 60% reduction from the BAU emissions in 2020 according to the REPA simulation results.
8. Such attempts to find win-win solutions by scaling up the amount of financial assistance failed due to technical reasons, mostly likely due to too large exogenous policy shocks.
9. A supply chain and a value chain are complementary views of an extended enterprise with integrated business processes enabling the flows of products and services in one direction, and of value as represented by demand and cash flow in the other. Both chains overlay the same network of actors. When we talk about supply chains, we usually talk about the direction from the source to the customer. Value flows the other way and the customer is the source of value.
10. 1 Mt = 10^6 t. In the original article, the authors calculated using the unit mega tonnes of carbon (Mt-C). Here we converted the unit to mega tonnes of CO_2 (Mt-CO_2) using the formula 1Mt-C=44/12Mt-CO_2.
11. For details, please refer to Miller and Blair (1985). For the application of MRIO, Peters and Hertwich (2008).
12. GDP-Energy elasticity measures the energy requirement for every unit of GDP of the country; the higher the elasticity, the higher the energy consumption for its economic activities, which thus measures the energy dependence of the economy.
13. 1 tera watt hour (Twh) = 10^9 kilo watt hour (Kwh).
14. A measure of available capacity over and above the capacity needed to meet normal peak demand levels. For a producer of energy, it refers to the capacity of a producer to generate more energy than the system normally requires. For a transmission company, it refers to the capacity of the transmission infrastructure to handle additional energy transport if demand levels rise beyond expected peak levels.
15. Greenfield power projects are those projects which are completely new and being carried out on empty land where it is not necessary to remodel or demolish existing structures.
16. A measurement used in the energy industry to calculate how efficiently a generator uses heat energy. It is expressed as the number of BTUs of heat required to produce a kilowatt-hour of energy.
17. Grid code covers the operating procedures and principles governing the interactions between the power producers, transmission companies and distribution companies to achieve a certain level of system reliability.

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