Carbon Emissions Embodied in International Trade: An assessment based on the multi-region input-output model

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ABSTRACT

The entry into force of the Kyoto Protocol to the United Nations Framework Convention on Climate Control (UNFCCC) divides parties into two groups by their obligations to mitigate domestic emissions. This division creates differences in the strictness of domestic climate policy, which are in favour of the conditions for creating the “heavens” of pollution. Current national GHG emissions accounting is based on territorial responsibility, or similarly producer responsibility, which contributes to make the conditions for creating the “heavens” of pollution mature. These situations lead to the concerns on global competitiveness and carbon leakage because carbon emissions embodied in international trade and associated global social costs are not taken into account. In addition, the equity of allocating full responsibility for emissions embodied in exports to the exporting countries is arguable. There is a need to consider other responsibility principles and take account of international trade.

Various policy measures have been suggested to address competitiveness and leakage concerns. Among others, the foremost policy option is to commit all emitting countries to reduce. Other measures include, e.g., border tax adjustment to level the international playing field. This report presents a policy option of national responsible emissions accounting adjusted by trade to address these issues.

The purpose of this report is (i) to assess and compare national emissions based on different principles of responsibility, including producer responsibility, consumer responsibility and shared producer and consumer responsibility based on value-added ratios; and (ii) to test the differences in the results calculated by different input-output models (the single-region input-output model and the multi-region input-output model). We conducted an empirical analysis for ten economies, including five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand), mainland China, Taiwan and three OECD countries (Japan, the Republic of Korea and the USA).

The empirical analysis indicates that CO_2 embodied in multilateral trade among ten selected economies is significant, accounting for 13% of the total national responsible emissions of ten economies. In terms of the trade balance of embodied CO_2, the USA (-464 Mt-CO_2), Japan (-191 Mt-CO_2) and Singapore (-13 Mt-CO_2) have a deficit while other economies, in particular China (452 Mt-CO_2), have a trade surplus. Our research indicates that carbon leakage occurs in a non-negligible way from developed economies to developing economies, which will undermine the efforts made in achieving the mitigation targets set by the Kyoto Protocol and should be properly considered by the UNFCCC.

This research demonstrates that a change from producer responsibility to consumer responsibility will greatly influence national emissions inventories. For example, the responsibility allocated by the two extreme methods, i.e., full producer responsibility vs. full consumer responsibility, could cause a change in the national emissions ranging from -525 to 543 Mt-CO_2 for different countries. This implies that trade adjustment to current national accounting to generate national responsible emissions accounts will influence the relationships between climate policy and international trade potentially and therefore can be considered as a complementary policy option, among others, to help address the carbon leakage concern. However, how consumer responsibility will influence carbon leakage and international competitiveness needs further assessment.

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1. Introduction

The greenhouse gas (GHG) concentrations in the atmosphere now stand at around 430 parts per million (ppm) CO_2 equivalent, compared with only 280 ppm before the Industrial Revolution (Stern, 2007). The stock is rising and emissions of carbon dioxide grew at an average annual rate of around 2.5% between 1950 and 2000, driven by increasing emissions from human activities including energy generation and land-use change. This will result in warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind.

According to the Stern Review (Stern, 2007), North America and Europe have produced around 70% of CO_2 emissions from energy production since 1850. Though developing countries account for less than one quarter of cumulative emissions, over three quarters of future emissions growth will likely come from today's developing countries because of more rapid population and GDP growth than developed countries and an increasing share of energy-intensive industries. Therefore all nations have a responsibility to protect the climate system, which is a shared resource.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) entered into force on 16 February 2005. Thirty-seven industrialised countries and the European Community have committed to collectively reduce their GHG emissions to an average of 5% against 1990 levels over the period 2008-2012. According to the principle of "common but differentiated responsibilities" and national respective capabilities, the Protocol does not commit developing countries to do so. During the 15th meeting of the Conference of the Parties of the UNFCCC, the Copenhagen Accord was concluded on 18 December 2009 with signatories agreeing that deep cuts in global emissions are required. Though new reduction targets have yet to be established, industrialised countries will further strengthen emissions reduction initiated by the Protocol and developing countries will implement nationally appropriate mitigation actions.

To establish quantified national reduction targets and to monitor the progress made to achieving them requires an assessment of national GHG emissions. Methods such as the reference approach and sectoral approach, currently adopted by the UNFCCC to estimate national GHG inventories, "include all greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (IPCC, 1996). These accounting methods are based on a principle of territorial responsibility (Eder and Narodoslawsky, 1999) or producer responsibility.

There are several advantages of accounting for national emissions based on the producer principle: (i) direct emissions generated from production are easier to be estimated and monitored; (ii) accounting for emissions within the boundary of national jurisdiction is compatible with the principle of sovereignty of states in international cooperation to address climate change which is endorsed by the UNFCCC; and (iii) producer responsibility is underpinned by the polluter-pays-principle which has been embraced by the OECD countries since 1974 (Neumayer, 2000).

However, there are also drawbacks in applying the principle of territorial responsibility. First, a region optimising its environmental strategy according to territorial responsibility is likely to relocate pollution-intensive production to regions with less stringent environmental regulation, the so-called "heavens" of pollution, and import the respective products. Some studies show that many countries become clean due to the out-sourcing of pollution (Rothman, 2000; Aldy, 2005; Cole and Elliott, 2005; Ekins, 2009; SERI et al., 2009; Weber and Peters, 2009). From the perspective of global sustainability, these countries would not be deemed sustainable (Pearce and Atkinson, 1993; Eder and Narodoslawsky, 1999; Proops et al., 1999).

Second, the Kyoto Protocol divides parties into two groups by their obligations to mitigate domestic emissions which creates differences in the strictness of domestic climate policy. Since emission reduction is costly, terms-of-trade will therefore be affected. Industries in countries which implement the reduction policy will face a competitive disadvantage compared to their international competitors that operate in countries which have not quantified reduction targets (Kemfert et al., 2004; van Asselt and Biermann, 2007; UNEP, 2009). As a consequence, carbon-intensive production will be pulled to countries that have less stringent climate policies along with other economic factors. Emissions reduced in Annex I countries through offshore carbon-intensive production and international trade will, however, generate elsewhere, in particular from developing countries. This potential trend of relocation has led to the concern of carbon leakage, which refers to an increase in CO_2 emissions in countries without climate policies due to emissions reduction in countries with climate policies in place. Carbon leakage can undermine the effectiveness of the Kyoto Protocol (Weber and Matthews, 2007; Peters and

Hertwich, 2008a) and become a central concern in the debates of climate change and international trade (Copeland and Taylor, 2005; World Bank, 2007; UNEP, 2009; van Asselt and Brewer, 2010).

Third, the equity of territorial GHG inventories has been argued by some major exporting countries. They produce goods that are consumed by other countries but carbon emissions are charged to their national emissions accounts. This is also argued as one of the barriers keeping developing nations from reduction commitments because many of them such as China, India and Southeast Asian countries, have experienced rapid economic development largely owing to the steady growth in exports, which contribute greatly to the increase in their territorial GHG emissions. Besides developing countries, open economies facing national CO_2 targets and having a big net export of CO_2 intensive goods, such as Denmark, are also concerned about a fairer responsibility principle (Munksgaard and Pedersen, 2001).

Against this background, international trade should be considered in future climate policy and there is a need to incorporate other principles of responsibility in assessing national emissions. In a large body of literature, "embodied emissions" is used as an indicator to account for emissions from each upstream stage of the supply chain of a product, which is used or consumed by the downstream stages or consumers, from "the cradle to the grave". Along with this is consumer responsibility proposed to address the driving forces of environmental pressures (Rose, 1990; Proops et al., 1993; Kondo et al., 1998; Eder and Narodoslawsky, 1999; Munksgaard and Pedersen, 2001; Lenzen et al., 2004; Peters and Hertwich, 2008a; Peters and Hertwich, 2008b). A national emissions inventory generated based on consumer responsibility includes emissions assessed based on producer responsibility plus emissions embodied in imports minus emissions embodied in exports. In addition, several articles proposed shared responsibility, including between exporting and importing countries (Kondo et al., 1998; Eder and Narodoslawsky, 1999; Peters, 2008), between production and consumption (Ferng, 2003;), or among upstream and downstream actors in a supply chain (Eder and Narodoslawsky, 1999; Bastianoni et al, 2004; Gallego and Lenzen, 2005; Lenzen et al., 2007).

Since the late 1990s, a large body of literature has emerged in estimating CO_2 emissions embodied in international trade. A clear message derived from these studies is that a significant amount of CO_2 is embodied in international trade. For example, CO_2 emitted inside Japan was estimated to be 1,115Mt-CO_2 in 1990[1], while carbon embodiments in the imports to Japan was 249Mt-CO_2, surpassing those embodied in Japan's exports (170Mt-CO_2) (Kondo et al., 1998). For Denmark, the CO_2 trade balance changed from a surplus of 0.5Mt in 1987 to a deficit of 7Mt 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, 2006a). For the USA, the overall CO_2 embodied in US imports grew from a range of 0.5 to 0.8Gt-CO_2 in 1997 to a range of 0.8 to 1.8Gt-CO_2 in 2004, representing between 9-14% and 13-30% of US national emissions in 1997 and 2004, respectively (Webber and Mattews, 2007). At the multi-regional level, about 13% of the total carbon emissions of six OECD countries (Canada, France, Germany, Japan, UK and USA) were embodied in their manufactured imports in the mid-1980s (Wyckoff and Roop, 1994). More recent research (Peters and Hertwich, 2008a) shows that around 5.3Gt, out of 42Gt CO_2 equivalent of global GHG emissions in 2000, were embodied in the international trade of goods and services and Annex B countries were found to be net importers of CO_2 emissions.

However, most of previous works focus mainly on developed countries and few of them measure the impacts on the national GHG inventories of developing nations. As the participation of developing countries in the mitigation of global warming is critical in achieving the stabilisation objective set by the UNFCCC, there is a need for an assessment on embodied emissions for developing countries.

To calculate embodied emissions, many studies use input-output analysis, an analytical framework developed by Wassily Leontief in the late 1930s (Leontief, 1936 and 1941) to deal with the interdependence of industries. An input-output model is originally applied to predict the impacts throughout an economy induced by a change in one industry. Since the late 1980s, input-output analysis has been widely used in environmental studies to account for emissions embodied in finished goods. Three types of input-output models are usually applied to account for emissions embodied in the imports of a particular country: the single-region input-output (SRIO) model, the model of emissions embodied in bilateral trade (EEBT), and the multi-region input-output (MRIO) model.

By the SRIO model, domestic technical coefficients (Miller and Blair, 1985) and emission intensities are applied to calculate CO_2 multipliers for imports irrespective of countries of

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[1] In the original paper, the authors use Mt-C as the unit for emissions accounting. The conversion factor from Mt-C to Mt-CO_2 is 44/12.

origin. This method is questionable because technologies and emission intensities vary from one country to another in producing similar products. In addition, summation of the results calculated by separate SRIO models at the global level will cause accounting errors.

As an improvement to the SRIO model, the EEBT model, which is established based on multiple SRIO models, emphasises emissions embodied in bilateral trade. Either regional input coefficients or regional technical coefficients (Miller and Blair, 1985), together with emission intensities in countries of origin are used to calculate CO_2 multipliers for imports, including both finished goods and intermediate products. However, treating the imports of intermediate commodities as exogenous variables fails to account for the interregional and inter-industrial feedback effects associated with the use of imported intermediate commodities (Miller, 1969; Round, 1979; Gillen and Guccione, 1980; Lenzen et al., 2004). In the case of using regional technical coefficients, the same kind of errors as mentioned above will occur at the global accounting level. In the case of using regional input coefficients, though accounting errors is not the question, the fairness of responsibility allocation will be another concern. For an extreme example, Country r produces 10-unit commodities, which are transshipped via Country s to Country t, where the commodities are finally consumed. Assume that the CO_2 multipliers of Country r, s and t are c_r, c_s and c_t, respectively, and $c_r < c_s$, $c_t < c_s$ and the transshipment via Country s contributes no more emissions. Based on the EEBT model, emissions embodied in the imports of 10-unit commodities to Country s from Country r will be $10c_r$, while emissions embodied in the imports of the same 10-unit commodities from Country s to Country t will be $10c_s$. Considering the balance of emissions embodied in trade, a negative amount of $10(c_r - c_s)$ (since $c_r < c_s$) will be allocated to the national inventory of Country s, while an amount of $10c_s$ will be charged to the national account of Country t. At the level of three countries, the total emissions from production are $10c_r$, which is equal to the total emissions assessed by consumer responsibility, i.e., 0 from Country r, $10(c_r - c_s)$ from Country s and $10c_s$ from Country t. However, the fairness of such allocation is arguable because it is rational to consider that $10c_r$ are charged to the national account of Country t rather than $10c_s$ ($>10c_r$).

In the MRIO model, a systematic and symmetric analytical framework, regional technical coefficients and emission intensities of countries of origin are used to estimate CO_2 multipliers for the imports of final commodities. Different from the EEBT model, intermediate commodities both produced domestically and imported are endogenously accounted for in CO_2 multipliers. The problems associated with other two models can be solved in the MRIO model.

The MRIO model is more appropriate and fairer to generate consumption-based national inventories at a multi-region level (Lenzen et al., 2004; Turner et al., 2007; Wiedmann et al., 2007).

In most existing literature, the SRIO model (e.g. by Kondo et al., 1998; Lenzen 1998; Munksgaard and Pedersen, 2001) and the EEBT (e.g. by Wyckoff and Roop, 1994; Nijdam et al., 2005; Peters and Hertwich, 2006b; Webber and Mattews, 2007; Peters and Hertwich, 2008a) are usually used. There are few studies which apply the MRIO model to account for emissions embodied in international trade (Weber and Matthews, 2007; Peters and Hertwich, 2007; McGregor et al., 2008). This is mainly due to the availability of data-intensive MRIO tables. A MRIO table is compiled based on SRIO tables and international trade data. Countries in a MRIO table are symmetrical to one another. Imports to each country are explicitly recorded by their source industry and by country of origin. In addition, the detailed use of imports by industries and by the final consumption is clearly documented. To generate such detailed and systematic accounts for each country in a MRIO table requires intensive data on international trade and compilation techniques to coordinate different presentations used in single-country IO tables and match different classification of sectors. These difficulties constrain the availability of MRIO tables compared to national input-output tables and therefore influence their extensive application.

In this context, the Institute for Global Environmental Strategies (IGES) initiated research on accounting for emissions embodied in international trade with particular focus on Asian developing countries. This research was supported by the IGES Strategy Fund in the fiscal year 2008. The purpose of this work was twofold. One was to assess and compare national emissions based on different principles of responsibility: (i) producer responsibility; (ii) consumer responsibility; and (iii) shared producer and consumer responsibility. The other was to test the differences in the results calculated by different input-output models: the SIRO model and the MRIO model. An empirical analysis was conducted for ten economies, including three OECD countries (Japan, ROK and USA), five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand), China and Taiwan. The rest of world (ROW) apart from the ten selected economies was also considered. These economies are covered due to the availability of the MRIO table.

The results of this research could be used to inform negotiators to the UNFCCC the implications of international trade for climate policy. Though international trade has many impacts on climate policy, either positive or negative, it has yet to receive proper consideration in the process of setting up a post-2012 global climate regime. This report can be used to stimulate the concerns on the relationships between international trade and climate policy. From a technical point of view, if national emissions accounting based on consumer responsibility will be used for providing complementary information to current national emissions inventories, this report can indicate how different accounting methods could influence national emissions inventories and therefore help select an appropriate assessment method. From a specific country's standpoint, this research also provides breakdowns of sources and destinations of embodied emissions and trade balance of CO_2.

This report is organised as follows: Section 2 provides a brief overview on different principles of responsibility. Section 3 explains the methodology and responsibility principles applied in the empirical analysis. Section 4 presents the results of the empirical analysis. Section 5 provides policy implications and concludes the report.

2. Producer vs. Consumer Responsibility: An Overview

National economies are increasingly interacting with each other through international trade, foreign direct investment, capital flow and the spread of technology. In a supply chain of a product, not all of the stages, from the extraction of raw materials, production and process, transportation and distribution until the delivery to the end users, occur in the same country. The cooperation among various agents located in different countries to complete the supply chain of a product is a phenomenon of economic globalisation, a process by which a spatially interwoven and sophisticated network of business and trade has been formed. As a consequence of this process, countries are bound economically to each other. A change in one country will have propagating effects on other economies.

From an environmental perspective, owing to global trade people have access to cheaper and better quality goods that are not produced domestically. However, emissions and other environmental loads may be generated elsewhere, in particular in developing countries where the environmental requirements are generally low. The environmental costs caused by damage to the environment, productivity and public health are usually not included in the price of finished goods and passed on to the consumers. This raises the question of who is responsible for the external costs associated with the production of goods for consumption in other countries/regions, via international trade. The essence of this question is the allocation of responsibility for emissions between the producer and the consumer.

2.1 Producer responsibility

Producer responsibility is supported by the well-recognised polluter-pays-principle which can be dated back to the 1970s. The rationale behind this is that the producer benefits from income generated from production and emissions are the unfavourable by-products. There are many other reasons for adopting the principle of producer responsibility. First, the producer has the best knowledge, capacity and jurisdiction to incorporate environmental considerations into the design and manufacturing of a product and to conduct emission abatement. Second, the producer as a business entity is convenient for the government to regulate, monitor and take statistics. Third, allocating emissions responsibility to the producer can create a strong and direct incentive to emitters to reduce emissions from production, which is the final goal of any environmental policy. The current national emissions inventories (IPCC, 1996) are generated based on producer responsibility in which a nation is responsible for all emissions emitted within her borders.

A further principle in line with this is extended producer responsibility (EPR) that aims to impose accountability over the entire life cycle of products, in particular the post-consumer stage. EPR has been introduced as a policy concept to the Organisation for Economic Co-operation and Development (OECD) countries. Policy instruments such as product take-back mandate and recycling rate targets, advance recycling fees and landfill bans, etc. (Walls, 2006) are developed to require firms, which manufacture, import and/or sell products and packaging, to be financially or physically responsible for the products.

A major concern over the adoption of producer responsibility in environmental policy is the “pollution heaven hypothesis”, which is caused by the relocation of polluting production to countries/regions with less strict environmental requirements and the corresponding imports of pollution-intensive products by countries with strict environmental policy in place. In climate policy, this is related to the concern of carbon leakage from Annex I countries to non-Annex I countries. In the Kyoto Protocol, only a sub-set of all emitting countries commit to the binding mitigation targets which creates a gap in national implementation of climate policy among parties to the UNFCCC. This will trigger the mechanism for relocation and makes the "heavens" of pollution exist, in particular in developing countries.

Another argument is about the equity of this principle because the consumer, in particular residing in a country other than the producing country, also benefits from an improvement in living standards and should share the responsibility for emissions. In addition, the producer responsibility principle has little incentive to the consumer to conserve the environment.

2.2 Consumer responsibility

On average, a European consumes three times as many resources as an inhabitant of Asia and more than four times as much as an average African. Inhabitants of other rich countries consume up to ten times more than people in developing countries (SERI et al., 2009). In OECD countries, overconsumption is increasingly recognised as the driving force of many anthropogenic impacts on the environment and the climate system. Dated back to the early 1990s, sustainable consumption and production is defined as an important component of sustainable development in Agenda 21. In recent years the focus of environmental policy in Europe has shifted from industrial pollution control towards establishing more sustainable consumption patterns and a number of policy measures have been adopted in the European Union (EU), e.g., the Sustainable Consumption and Production Action Plan (2008) (Ekins, 2009). This trend leads to an increasing need for proper assessment on the environmental impacts of the products consumed by the households. Consequently, consumer responsibility has emerged as a principle for such assessment.

There are several reasons to use consumer responsibility in environmental policy. First, consumption is the driving force of economic growth and income generation which are obtained at the expense of environmental damage. In applying the systematic framework, driving force–pressure–state–impact–response (DPSIR) and life-cycle management to addressing environmental problems, it is necessary to take consumer responsibility into account. Second, the consumer benefits from consumption in terms of increasing living standards. According to the beneficial responsibility, the consumer should be responsible for the emissions embodied in the product that he/she consumed. Third, in the current model of demand-driven market, environmental awareness among consumers and the resulting boycott and selective purchasing have been demonstrated as effective pressure on big corporations and multinationals to improve their environmental performance. Therefore consumer responsibility could be used as a complementary policy tool of the dominant command-and-control measures. Fourth, consumer responsibility might help to discourage carbon leakage. Since this principle seems to be more beneficial and fairer to developing countries, it might help to encourage more participation from developing countries in mitigation regime.

Since the 1980s, there is a growing literature on the estimation of emissions, energy, resources and ecological footprints embodied in household consumption (Denton, 1975; Herendeen, 1978; Common and Salma, 1992; Bicknell et al., 1998; Kondo et al., 1998; Lenzen, 1998; Ferng, 2001; Lenzen and Murray, 2001; Munksgaard and Pedersen, 2001; Hubacek and Giljum, 2003; Nijdam et al., 2005; Peters and Hertwich, 2006a; Peters and Hertwich, 2006b; Wiedmann et al., 2006; Zhou et al., 2006a and 2006b; Webber and Matthews, 2007; Mcgregor, 2008, etc.). In practice, consumer responsibility is used as the basis to generate national ecological footprints (Rees and Wackernagel, 2006; Wackernagel and Rees, 1996; WFF, 1998, 1999, 2000, 2002, 2004, 2006, 2008; Manfreda, 2004), an indicator used to reveal the overshoot of biological capacity at a global level. In addition, the consumer principle is applied to account for indirect GHG emissions categorised in Scope 2 and Scope 3 of the GHG Protocol to achieve carbon neutrality (DECC, 2009).

However, there are also drawbacks in using the principle of consumer responsibility. First, emissions accounting based on consumer responsibility is complicated and requires massive data on technology and international trade that is usually not available. Currently many studies use input-output analysis to assess national responsible emissions. However, highly aggregation of products into sectors will cause uncertainty in the results (Lenzen et al., 2004; Lenzen, 2007). Second, to generate effective pressure on the producer via consumer responsibility and therefore cause the change in production behaviour, it is necessary to have enough environmental awareness among consumers and available information on the environmental aspects of products. However, in many cases these conditions are not met. In addition, consumer pressure works as an indirect incentive to the producer to mitigate. Though many single cases demonstrate successfully, the effectiveness of such mechanism to ensure the achievement of global mitigation targets is still in question. Third, a big concern related to policy implementation based on consumer responsibility is territorial sovereignty. A country has political control over its jurisdiction however does not have the political power in other countries. To deal with this problem requires international cooperation.

2.3 Comparison of responsibility principles

Table 1 provides a list of different responsibilities and their comparison. These responsibility principles are summarised into two distinct categories. One is territorial emissions accounting for only direct emissions from a nation's territory based on the polluter-pays-principle. The other is national responsible emissions accounting for both direct emissions and indirect emissions associated with production and consumption of a country based on beneficial principle. For the latter category, there are several allocating schemes to account for indirect CO_2 emissions based on different system boundary and different actors (e.g., producer and consumer). Table 2 provides the implications of different responsibility principles for climate policy at both domestic level and the international level.

Table 1 Responsibility for CO_2 emissions based on different principles

Responsibility	Literature	Description	System Boundary	Accounting Measurement	Principle
Territorial responsible CO_2 emissions	Eder and Narodoslawsky, 1999.	A nation is responsible only for CO_2 emissions occurred directly in its territory.	A nation's territory.	Direct emissions from production and consumption.	Assign responsibility to polluters based on polluter-pays-principle.
National responsible CO_2 emissions	Common and Salma, 1992; Proops et al., 1993; Kondo et al., 1998.	A nation is (fully or partly) responsible for both direct CO_2 emissions and indirect CO_2 emissions embodied in international trade.	The respective nation and all of its trading partners (both importing and exporting)	Different approaches to account both direct and indirect emissions.	Assign responsibility to force drivers (e.g., consumers) based on beneficial principle.
Unrestricted beneficial responsibility	Eder and Narodoslawsky, 1999.	A nation is responsible for all activities from which the inhabitants of the region obtain benefits.	Domestic consumers and all trading partners to satisfy domestic consumption.	Direct emissions from final consumption and indirect emissions embodied in the international trade to satisfy the final consumption in the country.	Consumer is the end of any supply chain and is assigned full responsibilities to all emissions occurred in the supply chain. A full consumer-based responsibility with full life-cycle perspective based on beneficial principle.
Unrestricted production-oriented responsibility	Eder and Narodoslawsky, 1999.	A nation is responsible for its production with extensions to the upstream production in the supply chain wherever they are located.	Domestic producers and all trading partners associated with upstream supply.	Direct emissions from domestic producers and emissions embodied in the international trade of intermediate commodities.	Producer-based responsibility expanded to upstream responsibility based on polluter–pays-principle and partial beneficial principle.
Shared producer and consumer responsibility	Lenzen et al., 2007; Gallego and Lenzen, 2005.	Responsibility divided into mutually exclusive and collectively exhaustive portions is assigned to the different actors in the full supply chain.	All actors (e.g., producers as only suppliers, producers as both suppliers and consumers, and final consumers) in the full supply chain no matter where they located.	Direct emissions and emissions embodied in all upstream productions are shared between producer and its immediate consumer based on different allocation ratio.	Based on both polluter–pays-principle and beneficial principle.

Source: the Authors.

Table 2 Policy implications of different responsibility principles

	Annex I countries	Non-Annex I countries	Global climate policy
Territorial responsibility	With reduction commitments defined by the Kyoto Protocol, countries are likely (i) to transfer CO_2-intensive part of production chain to other countries, especially non-Annex I countries; and (ii) to import CO_2-intesive goods/services instead of producing by themselves. They could enjoy the benefit of less cost to attaining the binding reduction target without compromising their levels of consumption and living standard.	Without binding reduction commitments yet, countries are likely to generate income through exports of CO_2-intensive intermediate commodities and final goods and therefore increase their national GHG inventories. Countries with net carbon trade balance (carbon embedded in export is greater than carbon embedded in import) argue that their territorial CO_2 emissions should be attributed partly to their trading partners.	Carbon leakage issues: (i) CO_2 emissions associated with international transportation; and (ii) direct CO_2 emissions from production in non-Annex I countries embodied in the exports of intermediate commodities, final goods and services to Annex I countries. The reduction in Annex I countries through international trade only result in the relocation of emitting sources from Annex I countries to non-Annex I countries, but nothing to contribute to the global reduction. In addition, as technologies are less advanced and productions are dirtier in developing countries, this kind of global relocation of emitting sources via international trade would undermine global efforts to achieve mitigation target. Countries with net carbon balance in view of international trade question the fairness of territorial principle and refuse to participate in the binding reduction scheme.
Beneficial responsibility	They would consider the trade-offs among producing by themselves, importing from other countries and changing life style, etc.	To create income from export, they would improve their production to promote low carbon technologies.	Carbon leakage resulted from the relocation of CO_2-intesive production via international trade could be addressed. Technology transfer from Annex I countries to non-Annex I countries might happen when Annex I countries relocate CO_2-intensive production in non-Annex I countries. Fairer responsibility-sharing principle would encourage more non-Annex I countries' participation in global mitigation scheme.
Unrestricted beneficial responsibility	ibid.	ibid.	ibid. Problem: producers have less incentive to improve their production.
Unrestricted production-oriented responsibility	Relocation of CO_2-intensive production would take into account of upstream emissions and finally promote world-wide systematic life-cycle management of production.		Technological innovation would be promoted and emissions would be minimised in terms of systematic life-cycle management. Problems: (i) unsustainable life style could not be influenced substantially; and (ii) double counting.
Shared producer and consumer responsibility	All actors in the full supply chain no matter where they locate will be responsible for mutually exclusive portion of emissions. This would promote world-wide systematic life-cycle management, including both production and consumption. Life style change can also be expected.		Problem: the accounting system also requires international cooperation.

Source: the Authors.

3. An Empirical Analysis Focusing on Asia: Methodology

To fulfill the purpose of this research work, i.e., (i) to assess and compare national emissions based on different principles of responsibility; and (ii) to test the differences in the results calculated by different input-output models, we conduct an empirical analysis for ten economies, including nine in Asia and USA, an important trading partner with nine economies. They are five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand), China and Taiwan and three OECD countries (Japan, ROK and USA). These economies are covered due to the availability of the MRIO table. The rest of the world (ROW) apart from the ten selected economies is also considered.

3.1 Multi-region input-output model

In this work, we apply the Asian International Input-Output Table 2000 (AIO 2000) developed by IDE-JETRO (2006) to calculate CO_2 embodied in multilateral trade (Zhou, 2009). AIO 2000 includes 24 sectors and ten regions in Asia and the Pacific. It is the Chenery-Moses type of MRIO (Miller and Blair, 1985; Chenery, 1953; Moses, 1955). To calculate embodied CO_2 we use the GTAP-E database which provides data on CO_2 emissions from combustion of six types of fuels from 60 sectors (including capital goods, households and government) in 87 regions for 2001. By aggregating and matching sectors from 60 in GTAP-E (Dimaranan, 2006) to 24 in AIO 2000 (see Appendix A) and using sectoral outputs from the GTAP database, intensities of CO_2 emissions are calculated for 24 sectors in 2001 (see Appendix B). These are used for calculating embodied emissions.

The framework of AIO 2000 is illustrated by the simplified two-sector and two-region case (Table 3), in which intra-regional and interregional trade of both intermediate and final goods among two regions are made explicit by bivariates indicating the source and destination sectors and regions. For the full framework of AIO 2000, please see Appendix C.

The supply-demand relations based on AIO 2000 could be generalized as follows:

$$X = AX + F + E$$

Or at the regional level,

$$\begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^n \end{pmatrix} = \begin{pmatrix} A^{11} & A^{12} & \cdots & A^{1n} \\ A^{21} & A^{22} & \cdots & A^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A^{n1} & A^{n2} & \cdots & A^{nn} \end{pmatrix} \begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^n \end{pmatrix} + \begin{pmatrix} \sum_s F^{1s} \\ \sum_s F^{2s} \\ \vdots \\ \sum_s F^{ns} \end{pmatrix} + \begin{pmatrix} E^{1ROW} \\ E^{2ROW} \\ \vdots \\ E^{nROW} \end{pmatrix} \tag{1}$$

with X^r : total output of region *r*; $A^{rs} = X^{rs} / X^s$: transaction coefficient matrix representing ratios of trade from *r* to *s* to the total input of *s*; F^{rs} : final demand of *s* supplied by *r*; E^{rROW} : exports from *r* to .

Table 3 Simplified framework of AIO 2000 in a two-sector and two-region case

		Intermediate Demand				Final Demand		Export to *ROW*	Total Output
		s1r1	*s2r1*	*s1r2*	*s2r2*	*r*1	*r*2		
Supply	*s1r1*	x_{11}^{11}	x_{12}^{11}	x_{11}^{12}	x_{12}^{12}	f_1^{11}	f_1^{12}	e_1^{1ROW}	x_1^1
	s2r1	x_{21}^{11}	x_{22}^{11}	x_{21}^{12}	x_{22}^{12}	f_2^{11}	f_2^{12}	e_2^{1ROW}	x_2^1
	s1r2	x_{11}^{21}	x_{12}^{21}	x_{11}^{22}	x_{12}^{22}	f_1^{21}	f_1^{22}	e_1^{2ROW}	x_1^2
	s2r2	x_{21}^{21}	x_{22}^{21}	x_{21}^{22}	x_{22}^{22}	f_2^{21}	f_2^{22}	e_2^{2ROW}	x_2^2
Import from *ROW*		m_1^{ROW1}	m_2^{ROW1}	m_1^{ROW2}	m_2^{ROW2}				
Value-added		v_1^1	v_2^1	v_1^2	v_2^2				
Total input		x_1^1	x_2^1	x_1^2	x_2^2				

Note: *s1, s2, r1, r2*: sector 1, sector 2, region 1 and region 2, respectively; x_{ij}^{rs} : transaction of intermediate goods from sector *i* in *r* to sector *j* in *s,* where *i, j* =1, 2 representing two sectors and *r, s* = 1, 2 representing two regions; f_i^{rs} : final demands of *i* in *s* supplied from *r*; e_i^{rROW} : exports of *i* from *r* to *ROW*; m_j^{ROWs} : imports of *j* from *ROW* to *s*; x_i^r : total output of sector *i* in *r*; v_j^s : value added of sector *j* in *s*.

Eq. 2 and Eq. 3 are derived to indicate the final demand-induced production, based on the MRIO model and the SRIO model, respectively. B^{rs} is the Leontief multiplier derived from the MRIO model representing production in *r* induced by the per unit final output in *s*.

$$\begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^n \end{pmatrix} = \begin{pmatrix} B^{11} & B^{12} & \cdots & B^{1n} \\ B^{21} & B^{22} & \cdots & B^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ B^{n1} & B^{n2} & \cdots & B^{nn} \end{pmatrix} \left[\begin{pmatrix} \sum_s F^{1s} \\ \sum_s F^{2s} \\ \vdots \\ \sum_s F^{ns} \end{pmatrix} + \begin{pmatrix} E^{1ROW} \\ E^{2ROW} \\ \vdots \\ E^{nROW} \end{pmatrix} \right] \tag{2}$$

$$\begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^n \end{pmatrix} = \begin{pmatrix} (I-A^{11})^{-1} & 0 & \cdots & 0 \\ 0 & (I-A^{22})^{-1} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & (I-A^{nn})^{-1} \end{pmatrix} \times \left[\begin{pmatrix} \sum_{s\neq 1} A^{1s}X^s \\ \sum_{s\neq 2} A^{2s}X^s \\ \vdots \\ \sum_{s\neq n} A^{ns}X^s \end{pmatrix} + \begin{pmatrix} F^{11} + \sum_{s\neq 1} F^{1s} \\ F^{22} + \sum_{s\neq 2} F^{2s} \\ \vdots \\ F^{nn} + \sum_{s\neq n} F^{ns} \end{pmatrix} + \begin{pmatrix} E^{1ROW} \\ E^{2ROW} \\ \vdots \\ E^{nROW} \end{pmatrix} \right] \quad (3)$$

The system boundary for calculating the multipliers using the SRIO model (See Appendix D) and the MRIO model (See Appendix E) is different. By the MRIO model, intermediate inputs from ten regions are internalised in the multiplier calculation, while by the SRIO model only domestic intermediate inputs are internalised while the imports of intermediate goods from other nine regions are treated exogenously similarly to imported final goods.

Treating the imports of intermediate commodities as exogenous variables in the SRIO model fails to account for the inter-regional and inter-industrial feedback effects associated with the use of imported intermediate commodities (Miller, 1969; Lenzen et al., 2004; Peters, 2008; Peters and Hertwich, 2006a). In addition, the fairness of responsibility allocation will be another concern, in particular in the case of exports from one country to another country via the transshipment of a third country (see an example in the introduction section).

3.2 Two responsibility allocation schemes

Taking international trade into account, national responsible emissions are calculated based on two responsibility allocation schemes, viz., (i) consumer responsibility (Scheme I); and (ii) shared producer and consumer responsibility based on the ratio of value added (Gallego and Lenzen, 2005; Lenzen, 2007; Lenzen et al., 2007) (Scheme II). For Scheme I, both models of MRIO and SRIO are applied.

Given c^r (row vector with each element representing CO_2 emissions per unit industrial output in *r*), national territorial emissions, C^r_{prod}, is estimated as follows, in which producers are taking full responsibility:

$$C^r_{prod} = c^r X^r + C^r_{hh} \quad (4)$$

C_{hh}^{r} represents direct emissions from regional households. According to this accounting method, the amount of national emissions is influenced by factors such as sectoral carbon intensity, national production output and the share of carbon intensive sector in national economy. In this case emissions embodied in trade are not taken into account.

Scheme I: Consumer responsibility

Under Scheme I, we calculate using both models of MRIO and SRIO. By the MRIO model (SchI-MRIO), national responsible emissions include four parts: (i) emissions embodied in the final demands supplied domestically ($P1_M$); (ii) emissions embodied in the final demands provided by imports from other nine regions ($P2_M$); (iii) emissions embodied in imports (miscellaneous of intermediate and final goods) from *ROW* (regions other than ten regions) ($P3_M$); and (iv) direct emissions from regional households ($P4$).

$$C_{con\_M}^{s} = \underbrace{\left(\sum\nolimits_r c^r B^{rs}\right) F^{ss}}_{P1_M} + \underbrace{\sum\nolimits_{n \neq s} \left[\left(\sum\nolimits_r c^r B^{rn}\right) F^{ns}\right]}_{P2_M} + \underbrace{C_{im}^{s}}_{P3_M} + \underbrace{C_{hh}^{s}}_{P4} \tag{5}$$

C_{im}^{s} (Eq. 6) are emissions embodied in imports from *ROW* to *s*, which is calculated using emission coefficients and multipliers of *ROW*.

$$C_{im}^{s} = c^w B^w M^{ROWs} \tag{6}$$

with c^w : row vector indicating sectoral carbon intensity of *ROW*; B^w : Leontief multiplier for *ROW* derived from GTAP database; M^{ROWs} : imports from *ROW* to *s*.

Emissions embodied in the total exports of region *s* calculated using multi-regional multipliers includes two parts: (i) emissions embodied in exports to other nine regions ($P5_M$); and (ii) emissions embodied in exports to *ROW* ($P6_M$)

$$P5_M = \sum\nolimits_{n \neq s} \left[\left(\sum\nolimits_r c^r B^{rs}\right) F^{sn}\right] \tag{7}$$

$$P6_M = \left(\sum_r c^r B^{rs}\right) E^{sROW} \tag{8}$$

with E^{sROW} : exports from region *s* to *ROW*.

National trade balance of CO_2 is shown in Eq. 9.

$$C^s_{tb\_M} = (P5_M + P6_M) - (P2_M + P3_M) \tag{9}$$

Using the SRIO model under Scheme I (SchI-SRIO), national responsible emissions, $C^s_{con\_S}$ (Eq. 10), also includes four parts, $P1_S$, $P2_S$, $P3_S$ and $P4$. World average sectoral CO_2 intensity $c^{\overline{w}}$ and world input-output multiplier $B^{\overline{w}}$, derived from the GTAP database, are applied to estimate imports from other nine regions as well as from *ROW* (regions other than the ten regions).

$$C^s_{con\_S} = \underbrace{\left[c^s\left(I - A^{ss}\right)^{-1}\right]F^{ss}}_{P1_S} + \underbrace{\sum_{n\neq s}\left[\left(c^{\overline{w}}B^{\overline{w}}\right)\left(A^{ns}X^s + F^{ns}\right)\right]}_{P2_S} + \underbrace{c^{\overline{w}}B^{\overline{w}}M^{ROWs}}_{P3_S} + \underbrace{C^s_{hh}}_{P4} \tag{10}$$

Similarly, emissions embodied in total exports calculated using single-region multipliers also includes two parts $P5_S$ and $P6_S$.

$$P5_S = \sum_{n\neq s}\left[C^s\left(I - A^{ss}\right)^{-1}(A^{sn}X^n + F^{sn})\right] \tag{11}$$

$$P6_S = \left[C^s\left(I - A^{ss}\right)^{-1}\right]E^{sROW} \tag{12}$$

National trade balance of CO_2 calculated by the SRIO model is shown in Eq. 13.

$$C^s_{tb\_S} = (P5_S + P6_S) - (P2_S + P3_S) \tag{13}$$

According to the consumer responsibility, factors influencing total national emissions may include a mixture of levels of sectoral carbon intensity, multiplier, level of consumption, share of carbon intensive consumption in total consumption, and trade, etc.

Scheme II: Shared producer and consumer responsibility

Under Scheme II, emissions emitted from one sector are shared at a defined ratio (based on value-added) between this sector ($C1$) and its downstream demands, including both intermediate demands of downstream producers ($C2$), and final consumers and exports ($C3$) (Lenzen et al., 2007; Lenzen, 2007). These are calculated using the MRIO model (see Eq. 14).

$$cX = c(AX+F+E) = \underbrace{c[(I-\alpha)(AX+F+E)]}_{C1\text{: upstream producer}} + \underbrace{c(\alpha AX)}_{\substack{C2\text{: downstream}\\ \text{producer}}} + \underbrace{c[\alpha(F+E)]}_{\substack{C3\text{: final consumers}\\ \text{and exports}}} \qquad (14)$$

α is a diagonal matrix with each element α_i^r on the diagonal representing the ratio of non-factor external inputs in sector *i* in region *r* to *i*'s total external inputs. $(1-\alpha_i^r)$ is therefore the factor inputs as a ratio to the total external inputs, defined as follows (Eq. 15):

$$1-\alpha_i^r = v_i^r / (x_i^r - a_{ii}^{rr} x_i^r) \qquad (15)$$

with v_i^r: value added of sector *i* in *r*, representing factor inputs; $(x_i^r - a_{ii}^{rr} x_i^r)$ being the total external inputs in sector *i* in *r*.

The supply and demand relations derived from Eq. 14 using the MRIO model is shown in Eq. 16:

$$cX = [c(I-\alpha A)^{-1}] \times \{[(I-\alpha)(AX+F+E)] + \alpha F + \alpha E\} \qquad (16)$$

$c(I-\alpha A)^{-1}[(I-\alpha)(AX+F+E)]$ is the portion shared by the upstream producer (*S1*) while $c(I-\alpha A)^{-1}\alpha F$ and $c(I-\alpha A)^{-1}\alpha E$ are the portions shared by the final consumer (*S2*) in ten regions and exports to *ROW* (*S3*), respectively.

4. An Empirical Analysis Focusing on Asia: Results

4.1 National responsible emissions adjusted by trade

National responsible CO_2 emissions are calculated with trade adjustment based on SchI-MRIO (Eq. 5), SchI-SRIO (Eq. 10) and SchII-MRIO (Eq. 16). These accounts are then compared with the current national accounts estimated based on producer responsibility (Eq. 4). The focus is put on emissions embodied in multilateral trade among ten economies. Trade between each region and ROW is also calculated, but with less priority.

In Table 4 (SchI-MRIO), national responsible CO_2 emissions indicate that changes to current national emissions vary from -525Mt-CO_2 (China) to 543Mt-CO_2 (USA). By percentage, these changes range from -25% (Malaysia) to 42% (Singapore).

Table 4 National responsible emissions (SchI-MRIO, 2000)

(in Mt-CO_2)

Region	$P1_M$	$P2_M$	$P3_M$	$P4$	$C^s_{con\_M}$	C^r_{prod}	Difference [1]	Difference (%)[2]
IDN	133	4	25	53	215	273	-58	-21%
MYS	47	7	19	15	88	118	-30	-25%
PHL	36	3	11	17	67	69	-2	-3%
SGP	36	7	38	4	85	60	25	42%
THA	92	6	25	21	144	155	-11	-7%
CHN	2,252	9	79	311	2,651	3,176	-525	-17%
TWN	94	14	46	56	210	217	-7	-3%
ROK	267	11	76	88	442	435	7	2%
JPN	862	82	189	310	1,443	1,179	264	22%
USA	4,318	163	659	1,105	6,245	5,702	543	10%
Total	8,137	306	1,167	1,980	11,590	11,384	206	2%

Note: IDN: Indonesia; MYS: Malaysia; PHL: the Philippines; SGP: Singapore; THA: Thailand; CHN: China; TWN: Taiwan; ROK: the Republic of Korea; JPN: Japan; USA: the United States of America.

1. Equals to $C^s_{con\_M} - C^r_{prod}$;

2. Equals to $(C^s_{con\_M} - C^r_{prod}) / C^r_{prod} \times 100\%$.

In Table 5 (SchI-SRIO), national responsible emissions adjusted by trade show changes to current national emissions ranging from -518Mt-CO_2 (China) to 322Mt-CO_2 (USA) or from -23% (Indonesia) to 42% (Singapore) in terms of percentage change.

Table 5 National responsible emissions (SchI-SRIO, 2000)

(in Mt-CO_2)

Region	$P1_S$	$P2_S$	$P3_S$	$P4$	$C^s_{con\_S}$	C^r_{prod}	Difference	Difference (%)
IDN	128	11	19	53	211	273	-62	-23%
MYS	42	30	15	15	102	118	-16	-14%
PHL	33	11	9	17	70	69	1	1%
SGP	29	24	28	4	85	60	25	42%
THA	84	21	20	21	146	155	-9	-6%
CHN	2,214	68	65	311	2658	3,176	-518	-16%
TWN	82	47	38	56	223	217	6	3%
ROK	240	47	63	88	438	435	3	1%
JPN	769	107	155	310	1341	1,179	162	14%
USA	4,205	163	551	1,105	6,024	5,702	322	6%
Total	7,826	529	963	1,980	11,298	11,384	-86	-1%

Comparing two calculation results, $(\sum_s C^s_{con\_M} - \sum_s C^s_{con\_S})$ for ten regions indicates 2.6% of total consumption-based emissions, i.e. $\sum_r C^r_{prod}$. However, $(C^s_{con\_M} - C^s_{con\_S}) / C^r_{prod}$ at national level, is considerable, e.g. up to -12% for Malaysia. These are caused mainly by different emission multipliers (multi-region multipliers, single-region multipliers or multipliers of *ROW*) applied to imports and exports, and the way treating intermediate demands and the impacts of feedback effects.

Under Scheme II (Eq. 16), the focus is placed on responsibility shared among ten economies (Table 6). Changes range from a decrease of -327Mt-CO_2 (China) to an increase of 386Mt-CO_2 (USA). Changes in terms of percentage exhibit a range from -18% (Malaysia) to 38% (Singapore).

Table 6 National responsible emissions (SchII-MRIO, 2000)

(in Mt-CO_2)

Region	$S1$	$S2$	$P3_M$	$P4$	National emissions	C^r_{prod}	Difference	Difference (%)
IDN	131	41	25	53	250	273	-23	-8%
MYS	45	18	19	15	97	118	-21	-18%
PHL	30	12	11	17	70	69	1	1%
SGP	29	12	38	4	83	60	23	38%
THA	79	24	25	21	149	155	-6	-4%
CHN	1,891	568	79	311	2,849	3,176	-327	-10%
TWN	86	26	46	56	214	217	-3	-1%
ROK	197	78	76	88	439	435	4	1%
JPN	658	193	189	310	1350	1,179	171	15%
USA	3,097	1,227	659	1,105	6,088	5,702	386	7%
Total	6,243	2,199	1,167	1,980	11,589	11,384	205	2%

Note: $S1$: emissions shared by the region as a producer; $S2$: emissions shared by the region as a final consumer (Eq. 16); national emissions equal to ($S1+S2+P3_M+P4$).

4.2 Multilateral trade balance of embodied emissions

Table 7 presents sources and destinations of embodied CO_2 in multilateral trade (SchI-MRIO). Rows read CO_2 embodied in exports and columns read CO_2 embodied in imports. As a reference, the last three rows show CO_2 embodied in imports and exports and trade balance of CO_2 under SchI-SRIO Singapore, Japan and the USA have trade deficits, while the other countries have trade surpluses in terms of embodied CO_2. Among ten economies, the USA has the largest trade deficit (-464Mt-CO_2) followed by Japan (-191Mt-CO_2), while China has the largest trade surplus (452Mt-CO_2). In the case of SchI-SRIO, USA, Japan, Singapore, Taiwan, ROK and the Philippines have trade deficits and the other economies have trade surpluses of CO_2.

Table 7 Sources and destinations of embodied emissions (SchI-MRIO, 2000)

(in Mt-CO_2)

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
USA	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	19	11	38	25	79	46	76	189	659	
$P2_M + P3_M$	29	26	14	45	31	88	60	87	271	822	
$P5_M + P6_M$	45	43	15	32	42	540	66	95	80	358	
$C^s_{tb\_M}$	16	17	1	-13	11	452	6	8	-191	-464	
$P2_S + P3_S$	30	45	20	52	41	133	85	110	262	714	
$P5_S + P6_S$	93	60	19	27	49	699	81	109	100	391	
$C^s_{tb\_S}$	63	15	-1	-25	8	566	-4	-1	-162	-323	

Table 8 indicates the responsibility of emissions shared by an economy as an upstream producer (*S1* in Table 6) and the destinations of trade for which the responsibility is shared between two trading partners. Table 9 presents the source countries from which embodied emissions are shared by an economy as a consumer (*S2* in Table 6).

Table 10 indicates the bilateral trade balance of embodied CO_2 (SchI-MRIO). The USA and Japan have trade deficits of CO_2 in the bilateral relations with all other eight economies and ROW, while China has a trade surplus of CO_2 in relation with all other nine economies and ROW. In particular, the Sino-USA trade surplus of CO_2 is considerably large (101Mt-CO_2).

Table 8 Destinations with which embodied emissions is shared by an economy as an upstream producer (SchII-MRIO, 2000)

(in Mt-CO_2)

Region	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA	Total
IDN	103.7	0.7	0.4	0.3	0.6	2.2	1.4	4.4	13.5	4.2	131
MYS	0.2	37.5	0.3	1.3	0.4	0.7	0.5	0.4	1.8	2.2	45
PHL	0.0	0.2	25.5	0.0	0.1	0.2	0.3	0.2	1.2	2.6	30
SGP	0.1	0.3	0.1	26.9	0.1	0.2	0.1	0.1	0.2	0.5	29
THA	0.2	0.4	0.1	0.2	73.9	0.4	0.3	0.2	1.3	1.9	79
CHN	0.9	0.8	0.3	0.8	1.0	1,844	1.8	3.4	15.1	23.5	1,891
TWN	0.2	0.4	0.2	0.2	0.3	3.3	74.5	0.3	1.7	4.3	86
ROK	0.2	0.3	0.2	0.2	0.2	2.4	0.6	187.1	2.4	3.6	197
JPN	0.3	0.7	0.2	0.6	0.7	2.1	1.5	1.4	644.0	6.0	658
USA	0.4	0.8	0.4	0.7	0.6	2.1	2.1	2.5	8.6	3,079	3,097

Table 9 Source countries with which embodied emissions is shared by an economy as a consumer (SchII-MRIO, 2000)

(in Mt-CO_2)

Region	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA
IDN	40.2	0.2	0.0	0.2	0.1	0.1	0.2	0.1	0.8	2.0
MYS	0.1	16.8	0.1	0.5	0.3	0.2	0.5	0.1	1.1	2.0
PHL	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.5	1.3
SGP	0.0	0.2	0.1	10.0	0.1	0.1	0.1	0.1	0.3	0.7
THA	0.1	0.1	0.0	0.1	22.2	0.1	0.1	0.0	0.8	1.3
CHN	0.3	0.5	0.1	0.4	0.5	565.9	0.9	1.1	11.3	25.4
TWN	0.1	0.2	0.1	0.0	0.1	0.7	22.6	0.1	0.9	2.6
ROK	0.1	0.1	0.1	0.1	0.1	0.4	0.3	75.3	1.3	2.9
JPN	0.1	0.2	0.1	0.1	0.2	0.3	0.5	0.3	173.3	2.6
USA	0.1	0.2	0.1	0.2	0.2	0.5	0.9	0.6	2.6	1,186.5
Total	41	18	12	12	24	568	26	78	193	1,227

Table 10 Bilateral trade balance of embodied emissions (SchI-MRIO, 2000)

(in Mt-CO_2)

Region	IDN	MYS	PHL	SGP	THA	CHN	TWN	ROK	JPN	USA	ROW	Trade Balance
IDN	0.0	0.5	0.2	0.5	0.1	-1.1	0.3	0.1	2.1	6.0	7.4	16
MYS	-0.5	0.0	0.2	1.0	0.1	-1.5	0.4	0.1	2.5	5.7	8.8	17
PHL	-0.2	-0.2	0.0	-0.3	-0.1	-0.3	-0.2	-0.2	1.1	3.6	-1.7	1
SGP	-0.5	-1.0	0.3	0.0	-0.2	-1.6	0.2	0.0	0.3	2.0	-12.4	-13
THA	-0.1	-0.1	0.1	0.2	0.0	-1.7	0.0	0.0	2.2	4.5	6.3	11
CHN	1.1	1.5	0.3	1.6	1.7	0.0	1.5	3.4	49.9	101.3	290.1	452
TWN	-0.3	-0.4	0.2	-0.2	0.0	-1.5	0.0	-0.6	0.5	4.2	4.2	6
ROK	-0.1	-0.1	0.2	0.0	0.0	-3.4	0.6	0.0	2.4	7.2	1.1	8
JPN	-2.1	-2.5	-1.1	-0.3	-2.2	-49.9	-0.5	-2.4	0.0	4.1	-133.8	-191
USA	-6.0	-5.7	-3.6	-2.0	-4.5	-101.3	-4.2	-7.2	-4.1	0.0	-325.2	-464
ROW	-7.4	-8.8	1.7	12.4	-6.3	-290.1	-4.2	-1.1	133.8	325.2	0.0	155

5. Conclusions and Policy Implications

The entry into force of the Kyoto Protocol to UNFCCC divides parties into two groups by their obligations to mitigate domestic emissions. This division creates differences in the strictness of domestic climate policy, which are in favour of the conditions for creating the "heavens" of pollution. Contrarily, current national GHG accounting is based on territorial responsibility, or similar producer responsibility, which contributes to make the conditions for creating the "heavens" of pollution mature. These situations lead to the concerns on global competitiveness and carbon leakage because carbon emissions embodied in international trade and associated global social costs are not taken into account. In addition, the equity of allocating full responsibility for emissions embodied in exports to the exporting countries is also arguable.

Various policy measures have been suggested to address competitiveness and leakage concerns. Among others, the foremost policy option is to commit all emitting countries to reduce. Based on the results of the 15th meeting of the Conference of the Parties of the UNFCCC held in Copenhagen, to conclude an international agreement on full participation in emission reduction will remain an intractable challenge. Other measures (Neuhoff, 2008) include: (1) the free allocation of tradable emission allowances and expanding the scope and coverage of a scheme or state aid to mitigate the carbon costs imposed by the emissions trading scheme implemented in the EU; (2) trade measures at the border that discussed in the US and the EU to level up the international playing field; and (3) measures creating a similar carbon price through the conclusion of international (sectoral) agreements. This report presents national responsible emissions accounting adjusted by trade to help address these issues.

Our research indicates that CO_2 embodied in multilateral trade among ten selected economies is significant. It accounts for about 1,473 Mt-CO_2 or 13% of the total national responsible emissions of ten economies (11,590 Mt-CO_2, under SchI-MRIO). At a national level, it could reach as high as 53% (Singapore). The results from the empirical analysis also indicate that carbon leakage occurs in a non-negligible way from developed economies to developing economies. This will undermine the efforts made in achieving the mitigation targets set by the Kyoto Protocol and should be properly considered by the UNFCCC.

This research demonstrates that a change from producer responsibility to consumer responsibility will greatly influence national emissions inventories. For example, responsibility allocated by the two extreme methods, i.e., full producer responsibility vs. full consumer responsibility, could cause a change in national emissions from –525 to 543 Mt-CO_2 (SchI-MRIO). For different countries the influence will be different. In general, the national emissions inventories in countries with net exports of emissions will increase and in an opposite way, the national emissions inventories in countries with net imports of emissions will decrease. This clue implies that trade adjustment to current national accounting to generate national responsible emissions accounts influence the current relationships between climate policy and international trade potentially and therefore can be considered as a complementary policy option, among others, to help address the carbon leakage concern. The comparison of advantages and disadvantages of different policy options to address the issue of embodied carbon and competitiveness and carbon leakage concerns is included in our future research agenda. In addition, how consumer responsibility will influence carbon leakage and international competitiveness needs further assessment.

To conduct trade adjusted national emissions accounting, more data is required including bilateral trade and carbon intensity by sector/product and by country. Rarely is the latter one transparent nor is it provided by countries or by authoritative international organisations. Information on geographical identity, energy intensity and carbon intensity of tradable goods are important to inform environmentally-conducive purchasing decisions and should be addressed through the collaboration between global climate regime and international trade regime.

In allocating emission responsibility associated with international trade, full producer responsibility and full consumer responsibility are two extremes. Shared producer and consumer responsibility lie between them and can work as direct incentives to help change the environmental behaviours of both actors. In this paper the ratio of added value in total external inputs is used to define shares. However, this is only one of the alternative ratios, such as the proportion of imports to exports. Further study is necessary to help select a fair, effective and robust ratio for sharing responsibilities between upstream producers and downstream consumers.

Appendix A Sector Classification

	Sector definition in AIO 2000	Sector code in GTAP Data Base 6
1	Paddy	pdr
2	Other agricultural products	wht, gro, v_f, osd, c_b, pfb, ocr
3	Livestock and poultry	ctl, oap, rmk, wol
4	Forestry	frs
5	Fishery	fsh
6	Crude petroleum and natural gas	oil, gas
7	Other mining	coa, omn
8	Food, beverage and tobacco	cmt, omt, vol, mil, pcr, sgr, ofd, b_t
9	Textile, leather and related products	tex, wap, lea
10	Timber and wooden products	lum
11	Pulp, paper and printing	ppp
12	Chemical products	crp
13	Petroleum and petro products	p_c
14	Rubber products	crp
15	Non-metallic mineral products	nmm
16	Metal products	i_s, nfm, fmp
17	Machinery	ele, ome
18	Transport equipment	mvh, otn
19	Other manufacturing products	omf
20	Electricity, gas, and water supply	ely, gdt, wtr
21	Construction	cns
22	Trade and transport	trd, otp, wtp, atp
23	Services	cmn, ofi, isr, obs, ros, dwe
24	Public administration	osg

Appendix B Carbon Intensities of 24 Sectors

(in kg/10^3 US$[1])

	IDN	MYS	PHL	SGP	THA	CHN	TWN	ROK	JPN	USA
1	1.58	15.01	2.40	0.04	63.77	132.87	215.10	315.57	140.41	1048.49
2	68.59	17.44	20.77	0.09	266.78	157.53	341.46	474.04	199.37	282.77
3	122.10	1.96	14.93	0.00	158.53	199.59	15.92	698.27	29.86	129.49
4	619.08	62.24	398.39	0.83	150.15	342.39	660.65	262.47	316.30	85.27
5	1048.67	107.17	483.73	0.16	1740.43	520.00	0.00	3372.10	1298.38	778.68
6	1645.06	0.05	13708.34	20362.47	0.99	1627.47	2720.06	619.37	23.05	714.71
7	564.96	2527.90	490.85	122.80	191.33	821.43	307.15	415.76	214.13	9.47
8	111.07	163.78	116.60	3.51	135.46	203.05	203.13	143.46	33.59	84.21
9	245.89	192.93	123.21	5.23	77.33	88.74	496.29	279.77	115.15	59.08
10	12.88	76.57	56.28	2.74	56.52	110.37	10.10	148.40	5.64	57.37
11	462.37	395.70	671.03	6.37	341.31	351.84	286.23	476.12	118.21	165.43
12	708.53	32.93	181.56	18.65	525.58	459.50	336.83	155.71	15.15	222.56
13	2262.61	3963.40	0.06	0.00	0.02	45.30	0.00	0.00	0.00	594.06
14	708.53	32.93	181.56	18.65	525.58	459.50	336.83	155.71	15.15	222.56
15	5986.40	453.09	1193.32	8.15	1023.63	1122.33	729.77	742.31	378.33	523.85
16	1260.65	249.14	149.38	10.06	310.18	685.06	577.23	135.15	177.65	180.27
17	53.12	29.04	2.94	3.09	27.30	65.65	28.10	22.70	11.48	21.97
18	22.34	108.93	0.96	4.05	8.59	118.40	27.27	98.17	1.12	33.44
19	373.32	175.54	5.61	14.77	73.01	14.93	62.68	243.33	46.48	15.58
20	9908.56	5753.85	2399.03	19460.36	5323.57	17701.69	2972.71	1794.26	658.12	6615.91
21	92.36	175.76	74.33	0.00	60.02	55.52	68.27	64.30	14.91	8.00
22	1502.79	1028.27	1281.42	0.57	889.22	550.96	804.17	1376.60	292.76	384.65
23	59.73	18.47	68.12	0.19	9.88	62.77	20.71	101.85	35.96	16.85
24	75.18	54.63	75.78	0.68	12.18	232.94	58.09	198.27	109.56	26.93

Note 1: US$ at 2000 value.

Appendix C Framework of AIO 2000 Table

Code	Intermediate Demand (A)										Final demand (F)										Export (L)			Statistical Discrepancy (QX)	Total Outputs (XX)
	Indonesia (AI)	Malaysia (AM)	Philippines (AP)	Singapore (AS)	Thailand (AT)	China (AC)	Taiwan (AN)	Korea (AK)	Japan (AJ)	U.S.A. (AU)	Indonesia (FI)	Malaysia (FM)	Philippines (FP)	Singapore (FS)	Thailand (FT)	China (FC)	Taiwan (FN)	Korea (FK)	Japan (FJ)	U.S.A. (FU)	Export to Hong Kong (LH)	Export to EU (LO)	Export to R.O.W. (LW)		
Indonesia (AI)	A^{II}	A^{IM}	A^{IP}	A^{IS}	A^{IT}	A^{IC}	A^{IN}	A^{IK}	A^{IJ}	A^{IU}	F^{II}	F^{IM}	F^{IP}	F^{IS}	F^{IT}	F^{IC}	F^{IN}	F^{IK}	F^{IJ}	F^{IU}	L^{IH}	L^{IO}	L^{IW}	Q^{I}	X^{I}
Malaysia (AM)	A^{MI}	A^{MM}	A^{MP}	A^{MS}	A^{MT}	A^{MC}	A^{MN}	A^{MK}	A^{MJ}	A^{MU}	F^{MI}	F^{MM}	F^{MP}	F^{MS}	F^{MT}	F^{MC}	F^{MN}	F^{MK}	F^{MJ}	F^{MU}	L^{MH}	L^{MO}	L^{MW}	Q^{M}	X^{M}
Philippines (AP)	A^{PI}	A^{PM}	A^{PP}	A^{PS}	A^{PT}	A^{PC}	A^{PN}	A^{PK}	A^{PJ}	A^{PU}	F^{PI}	F^{PM}	F^{PP}	F^{PS}	F^{PT}	F^{PC}	F^{PN}	F^{PK}	F^{PJ}	F^{PU}	L^{PH}	L^{PO}	L^{PW}	Q^{P}	X^{P}
Singapore (AS)	A^{SI}	A^{SM}	A^{SP}	A^{SS}	A^{ST}	A^{SC}	A^{SN}	A^{SK}	A^{SJ}	A^{SU}	F^{SI}	F^{SM}	F^{SP}	F^{SS}	F^{ST}	F^{SC}	F^{SN}	F^{SK}	F^{SJ}	F^{SU}	L^{SH}	L^{SO}	L^{SW}	Q^{S}	X^{S}
Thailand (AT)	A^{TI}	A^{TM}	A^{TP}	A^{TS}	A^{TT}	A^{TC}	A^{TN}	A^{TK}	A^{TJ}	A^{TU}	F^{TI}	F^{TM}	F^{TP}	F^{TS}	F^{TT}	F^{TC}	F^{TN}	F^{TK}	F^{TJ}	F^{TU}	L^{TH}	L^{TO}	L^{TW}	Q^{T}	X^{T}
China (AC)	A^{CI}	A^{CM}	A^{CP}	A^{CS}	A^{CT}	A^{CC}	A^{CN}	A^{CK}	A^{CJ}	A^{CU}	F^{CI}	F^{CM}	F^{CP}	F^{CS}	F^{CT}	F^{CC}	F^{CN}	F^{CK}	F^{CJ}	F^{CU}	L^{CH}	L^{CO}	L^{CW}	Q^{C}	X^{C}
Taiwan (AN)	A^{NI}	A^{NM}	A^{NP}	A^{NS}	A^{NT}	A^{NC}	A^{NN}	A^{NK}	A^{NJ}	A^{NU}	F^{NI}	F^{NM}	F^{NP}	F^{NS}	F^{NT}	F^{NC}	F^{NN}	F^{NK}	F^{NJ}	F^{NU}	L^{NH}	L^{NO}	L^{NW}	Q^{N}	X^{N}
Korea (AK)	A^{KI}	A^{KM}	A^{KP}	A^{KS}	A^{KT}	A^{KC}	A^{KN}	A^{KK}	A^{KJ}	A^{KU}	F^{KI}	F^{KM}	F^{KP}	F^{KS}	F^{KT}	F^{KC}	F^{KN}	F^{KK}	F^{KJ}	F^{KU}	L^{KH}	L^{KO}	L^{KW}	Q^{K}	X^{K}
Japan (AJ)	A^{JI}	A^{JM}	A^{JP}	A^{JS}	A^{JT}	A^{JC}	A^{JN}	A^{JK}	A^{JJ}	A^{JU}	F^{JI}	F^{JM}	F^{JP}	F^{JS}	F^{JT}	F^{JC}	F^{JN}	F^{JK}	F^{JJ}	F^{JU}	L^{JH}	L^{JO}	L^{JW}	Q^{J}	X^{J}
U.S.A. (AU)	A^{UI}	A^{UM}	A^{UP}	A^{US}	A^{UT}	A^{UC}	A^{UN}	A^{UK}	A^{UJ}	A^{UU}	F^{UI}	F^{UM}	F^{UP}	F^{US}	F^{UT}	F^{UC}	F^{UN}	F^{UK}	F^{UJ}	F^{UU}	L^{UH}	L^{UO}	L^{UW}	Q^{U}	X^{U}
Freight & Insurance (BF)	BA^{I}	BA^{M}	BA^{P}	BA^{S}	BA^{T}	BA^{C}	BA^{N}	BA^{K}	BA^{J}	BA^{U}	BF^{I}	BF^{M}	BF^{P}	BF^{S}	BF^{T}	BF^{C}	BF^{N}	BF^{K}	BF^{J}	BF^{U}					
Import from HK (CH)	A^{HI}	A^{HM}	A^{HP}	A^{HS}	A^{HT}	A^{HC}	A^{HN}	A^{HK}	A^{HJ}	A^{HU}	F^{HI}	F^{HM}	F^{HP}	F^{HS}	F^{HT}	F^{HC}	F^{HN}	F^{HK}	F^{HJ}	F^{HU}					
Import from EU (CO)	A^{OI}	A^{OM}	A^{OP}	A^{OS}	A^{OT}	A^{OC}	A^{ON}	A^{OK}	A^{OJ}	A^{OU}	F^{OI}	F^{OM}	F^{OP}	F^{OS}	F^{OT}	F^{OC}	F^{ON}	F^{OK}	F^{OJ}	F^{OU}					
Import from R.O.W.	A^{WI}	A^{WM}	A^{WP}	A^{WS}	A^{WT}	A^{WC}	A^{WN}	A^{WK}	A^{WJ}	A^{WU}	F^{WI}	F^{WM}	F^{WP}	F^{WS}	F^{WT}	F^{WC}	F^{WN}	F^{WK}	F^{WJ}	F^{WU}					
Duties & taxes (DT)	DA^{I}	DA^{M}	DA^{P}	DA^{S}	DA^{T}	DA^{C}	DA^{N}	DA^{K}	DA^{J}	DA^{U}	DF^{I}	DF^{M}	DF^{P}	DF^{S}	DF^{T}	DF^{C}	DF^{N}	DF^{K}	DF^{J}	DF^{U}					
Value added (VV)	V^{I}	V^{M}	V^{P}	V^{S}	V^{T}	V^{C}	V^{N}	V^{K}	V^{J}	V^{U}															
Total inputs (XX)	X^{I}	X^{M}	X^{P}	X^{S}	X^{T}	X^{C}	X^{N}	X^{K}	X^{J}	X^{U}															

Source: IDE-JETRO (2006).

Appendix D Carbon Multipliers of 24 Sectors Calculated by the SRIO Model

(in kg/10^3 US$)

	IDN	MYS	PHL	SGP	THA	CHN	TWN	ROK	JPN	USA
1	99.82	215.27	62.40	0.04	174.18	1363.87	310.41	378.36	198.13	1048.49
2	218.45	281.73	123.75	348.60	434.22	1337.86	474.89	606.68	266.06	662.16
3	487.22	660.37	232.88	383.50	615.74	1057.07	326.57	1194.82	187.80	740.16
4	813.81	377.01	520.40	0.83	245.88	1075.80	830.22	365.79	409.17	257.77
5	1288.27	1155.60	654.30	1109.82	1972.38	1423.01	112.06	3596.92	1420.05	1022.52
6	2004.24	79.44	13818.42	20362.47	116.37	3467.10	2842.71	619.37	115.36	1021.05
7	805.15	3105.32	665.02	1089.88	467.43	3935.89	405.65	608.53	317.83	446.08
8	594.66	908.15	420.90	287.62	646.68	1526.09	466.20	714.71	203.72	500.15
9	1020.90	688.24	291.64	293.63	704.74	1487.56	945.54	641.61	244.96	441.24
10	747.93	549.76	408.89	352.30	406.37	2208.89	195.67	465.21	137.59	387.68
11	1178.09	968.38	987.52	326.29	712.57	2653.00	548.35	973.16	257.80	530.74
12	1457.89	808.06	492.67	617.91	1099.96	3870.98	593.34	479.57	146.97	667.73
13	2920.29	4423.62	103.63	97.52	98.54	2390.50	60.70	54.80	30.28	1292.59
14	1232.74	535.50	326.96	431.62	1052.18	2663.91	588.77	430.65	138.99	590.01
15	7198.90	1599.89	1856.05	596.20	1874.11	4674.91	1043.79	1231.44	548.82	1072.82
16	2347.15	696.84	519.98	455.10	764.52	4632.84	974.30	482.95	378.27	597.17
17	735.48	258.29	131.12	188.18	282.21	2138.44	223.64	240.48	135.21	245.59
18	661.65	402.35	389.15	270.84	302.65	2188.89	246.91	420.48	131.09	298.98
19	1154.85	615.80	183.11	444.28	529.78	2282.96	364.44	593.33	177.60	318.01
20	11794.58	6520.00	3036.89	21999.86	6539.42	20918.44	2999.72	2103.75	749.27	7491.32
21	1230.44	734.77	344.83	223.48	671.10	2537.59	430.08	375.75	158.42	295.92
22	2021.79	1397.94	1546.08	201.95	1138.80	1910.43	866.59	1543.86	351.40	603.30
23	498.47	275.00	281.28	365.70	443.01	1523.06	90.05	279.11	97.05	186.55
24	512.67	399.73	205.88	317.52	469.49	1739.45	140.86	346.59	164.23	286.41

Appendix E Carbon Multipliers of 24 Sectors Calculated by the MRIO Model

(in kg/10^3 US$)

	IDN	MYS	PHL	SGP	THA	CHN	TWN	ROK	JPN	USA
1	116.31	283.42	83.83	0.04	242.02	1381.21	332.83	394.88	214.29	1048.49
2	234.54	347.50	170.94	477.31	482.84	1354.49	510.10	638.49	282.19	672.09
3	505.35	746.54	272.97	544.26	654.83	1069.44	385.20	1255.80	219.88	753.24
4	827.02	417.92	564.90	0.83	262.29	1091.98	860.13	382.38	418.28	272.37
5	1300.35	1207.32	695.57	1298.22	2022.50	1438.02	185.91	3652.03	1453.33	1030.04
6	2011.94	109.17	13856.49	20362.47	139.80	3486.37	2864.82	619.37	126.85	1029.53
7	819.60	3198.06	726.21	1189.34	503.49	3966.16	464.50	636.57	341.05	457.21
8	623.42	1036.18	472.64	545.92	720.84	1548.82	560.00	795.08	243.27	512.02
9	1137.17	963.11	544.90	505.50	848.55	1551.16	1077.96	794.77	310.74	491.90
10	785.42	658.39	522.37	558.91	503.26	2265.08	315.45	594.97	201.98	411.99
11	1246.76	1172.88	1153.87	471.28	844.92	2744.63	654.13	1075.97	283.45	542.43
12	1562.63	1002.11	721.30	793.03	1267.81	3924.90	794.82	664.13	211.39	686.57
13	2995.48	4513.09	173.41	396.29	201.03	2428.59	203.09	195.48	111.54	1304.14
14	1338.34	710.40	616.53	637.09	1166.37	2729.86	724.07	581.95	190.04	626.85
15	7254.21	1774.91	2074.70	863.44	1983.67	4714.69	1208.11	1329.86	594.29	1096.51
16	2456.90	980.91	806.00	727.94	953.99	4681.68	1155.96	648.59	436.74	626.33
17	845.97	506.38	308.38	422.95	528.24	2206.32	411.81	373.98	184.33	289.57
18	726.10	574.73	634.25	446.32	446.03	2235.84	359.13	526.06	171.48	337.05
19	1300.30	818.04	377.26	652.95	688.86	2354.79	514.14	714.57	231.83	342.13
20	11819.37	6565.22	3165.72	22137.62	6565.83	20945.41	3004.88	2210.71	813.67	7498.07
21	1313.46	922.93	469.70	409.90	791.52	2582.01	531.83	441.72	190.19	320.51
22	2044.15	1434.48	1595.66	278.45	1170.09	1934.97	887.63	1580.28	359.73	609.29
23	515.66	323.98	322.00	430.76	486.19	1548.80	108.95	303.03	107.75	192.66
24	533.06	472.35	229.07	420.03	506.47	1763.00	166.74	373.66	172.40	294.97

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