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The Greenhouse Stakes of Globalization

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1. Introduction

As 2012 approaches, twenty-five years have passed since the Brundtland report defining sustainable development as a progress that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations). Currently, the fight against Climate change constitutes one of the main features of worldwide policies towards sustainable development. Furthermore, the global climate change issue benefits from an international discussion area through the United Nations framework convention on climate change (UNFCCC). This convention was created during the first Earth summit, which was held in Rio in 1992 and benefits from the scientific support of the Intergovernmental Panel on Climate Change (IPCC) created in November 1988. The ultimate objective of this convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (United Nations, 1992). Thus far, the 1997 Kyoto protocol constitutes the main achievement of this convention of which we propose to briefly remind the objectives and analyze the policy patterns in **2.1**.

During the same period, the world is known to have experienced an unprecedented wave of globalization. Such globalization is characterized by the increasing number of countries taking part in international trade and the growing number of traded items both in variety, quantity, and value. **Figure 1** shows the world production and the associated globalization expressed in terms of world GDP fraction associated with exports have been respectively multiplied by 45 and 2.5 over the last fifty years. Nevertheless, over the 1960 – 2008 periods, it should be noted the same three regions[1] cover over half of the world GDP. It thus seems the globalization process has so far mainly consisted in a redistribution of GDP strength between these regions.

Another key point in the globalization process is the increasing sophistication of modern supply chains. Indeed, the application of modern management principles throughout the supply chain such as Just-In-Time, lean production and Efficient Consumer Response have led to more responsive, more flexible supply chains that enable firms to compete in a global

[1] **Western Europe**: Austria, Belgium, France, Germany, Luxembourg, Netherlands, Switzerland.
East Asia: China, Hong Kong, Macao, North Korea, Japan, Mongolia, South Korea.
Northern America: Bermuda, Canada, Greenland, Saint Pierre and Miquelon, USA.

market. Furthermore, the potential extension of trade partners encourages companies to experience global sourcing strategies and wider distribution of finished products (Cetinkaya, et al., 2011). All these new aspects of trade tend to increase the need for freight transportation and particularly for international freight transportation whose associated emissions were not addressed by the Kyoto Protocol. Indeed, the inclusion of these emissions constitutes the main debate of Post-Kyoto mitigation policies.

The objective of this chapter is thus to link globalization to global climate change via:

- A policy and macro-economic perspective in framing the stakes linked to the increasing importance of GHG emissions associated with trade and freight transportation for the definition of Post-Kyoto GHG reduction strategies.
- A micro-economic or trade perspective in framing the stakes and challenges of product carbon labeling policies and carbon accounting, notably those associated with freight transportation.

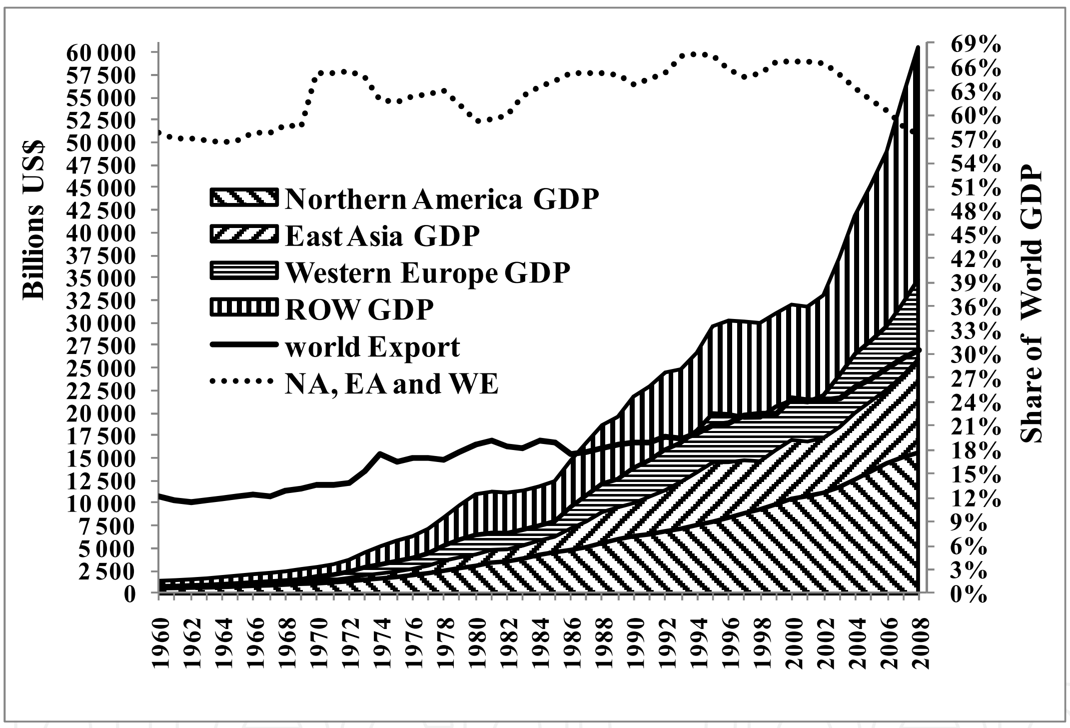

Fig. 1. The evolution of world, Northern America, East Asia and Western Europe GDP together with the corresponding fraction of world GDP in the 1960-2008 period

2. How to frame reduction of GHG emissions from freight transportation in a global economy?

2.1 Kyoto Protocol and GHG mitigation policy backgrounds

In 2011, the 193 member states of the United Nations have signed the Kyoto Protocol except Afghanistan, Andorra, and South Sudan (United Nations). Nevertheless, there are 193 signatories of the Kyoto Protocol as Cook Islands and Niue are considered as additional states and European Union as an added economic region. Among these 193 signatories, only the United States has not ratified the Protocol (United Nations). Being able to unify all these countries around global climate change issue constitutes without doubt an international policy success but only 41 countries[2] grouped under the "Annex I" label are mandated with GHG emission reduction targets. Following the principles of historical responsibility and the right to development of developing and emerging countries, the UNFCCC determined on December 11th 1997 in Kyoto that reduction targets should first applied to developed countries. Therefore, Annex I countries are mainly developed countries and the Article 3 of the UNFCCC Kyoto protocol sets their GHG emissions must be at least 5 % below 1990 levels for the commitment period 2008 to 2012(United Nations). On the other hand, non-Annex I countries are only encouraged to elaborate and publish methodologies and datasets of the GHG emissions associated with their activities (United Nations). Therefore, build a comprehensive worldwide dataset of GHG emissions may be complicated due to the uncertainties associated with non-Annex I GHG emissions. Nevertheless, the 1990 reference emissions associated with Annex I countries represent as much as 63.7% of 1990 worldwide GHG emissions (United Nations). Furthermore, the Kyoto Protocol entered only into force on February 16th 2005 after more than 55% of 1990 GHG emissions of Annex I countries was concerned by the Protocol. These last figures means the lowest worldwide GHG emissions reduction target set by the Kyoto Protocol corresponds to a 1.8% reduction of the 1990 world GHG emissions[3]. Consequently, three main questions need to be addressed in regards to the Kyoto policy success:

- Has the reduction targets been reached for Annex I countries?
- How much represent Annex I countries GHG emissions in today's world?
- What has been the evolution of worldwide GHG emissions for the last twenty years?

The Annex I countries GHG emissions dropped from 18.73 $GtCO_2$ in 1990 to 17.76 $GtCO_2$ in 2008 thus achieving a 5.2% reduction in emissions. When comparing the average GHG annual emission level of the 1990-2008 periods with the 1990 emission level, the reduction achieved is 5.3%. Therefore, from the viewpoint of the reduction targets set for Annex I countries, the Kyoto protocol has reached its objectives. However, this success covers different stories as shown in **Figure 2**. Actually, Annex I countries without emission reduction targets has known a 10% increase of their average GHG annual emission while those with emissions reduction targets followed an opposite trend with a 13% decrease of average annual emission level. Consequently, Annex I countries without GHG emission targets of which the United States constitutes the main contributor (95%) represent 42% of total Annex I GHG emissions in 2008 against 34% in 1990. Furthermore, within the Annex I countries with targets, four main trends clearly appear:

- Countries with high increase in emission **(Canada , Oceania)**

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[2] ***Non-EU Europe***: Belarus*, Croatia (-5%), Iceland (+10%), Liechtenstein (-8%), Monaco (-8%), Norway (+1%), Switzerland (-8%), Russian Federation (+0%), Ukraine (0%) ***EU27***: Bulgaria (-8%), Romania (-8%) ***EU25***: Czech Republic (-8%), Estonia (-8%), Hungary (-6%), Latvia (-8%), Lithuania (-8%), Malta*, Poland (-6%), Slovakia (-8%), Slovenia (-8%) ***EU15***: Austria (-8%), Finland (-8%), Sweden (-8%) ***EU12*** : Denmark (-8%), Greece (-8%), Ireland (-8%), Portugal (-8%), Spain (-8%), United Kingdom (-8%) ***EU6***: Belgium (-8%), France (-8%), Germany (-8%), Italy (-8%), Luxembourg (-8%), Netherlands (-8%) ***Oceania:*** Australia (+8%), New Zealand (+0%) ***Asia***: Japan (-6%), Turkey* ***America***: Canada (-6%), United States* (-7%)* ***Without target Annex I countries*** (United Nations)

[3] 5% reduction*55 % of Annex I GHG emissions*63.7% of world GHG emission=1.8% of world GHG emissions

- Countries with slow increase in emission **(Japan, Other EU6, EU12, EU15)**
- Countries with slow decrease in emission **(France)**
- Countries with high decrease in emission **(Russian Federation, Other Non-EU, Germany, EU25, EU27)**

Interestingly, while a 6.1% reduction of French GHG emissions is achieved in 2008 compared to 1990 level, this reduction drops to 0.9% when considering the average annual French GHG emissions of the 1990-2008 periods. Respectively, Japanese emissions increase from 1% to 4.7%. Therefore, though most statistics regarding climate change compares directly the 2008 emission level to those of 1990, we argue that considering the level of emissions averaged over the 1990-2008 periods better captures the historical evolution of GHG emissions. Indeed, the 2008 GHG emissions may correspond to a crisis year with low level of activities, thus setting a low GHG emission reference. Furthermore, in the perspective of an achievement of GHG emission reduction over the 2008-2012 periods and beyond, one needs to ensure the achieved GHG emission reduction are not cyclical and will not rise up as soon as the crisis period has ended.

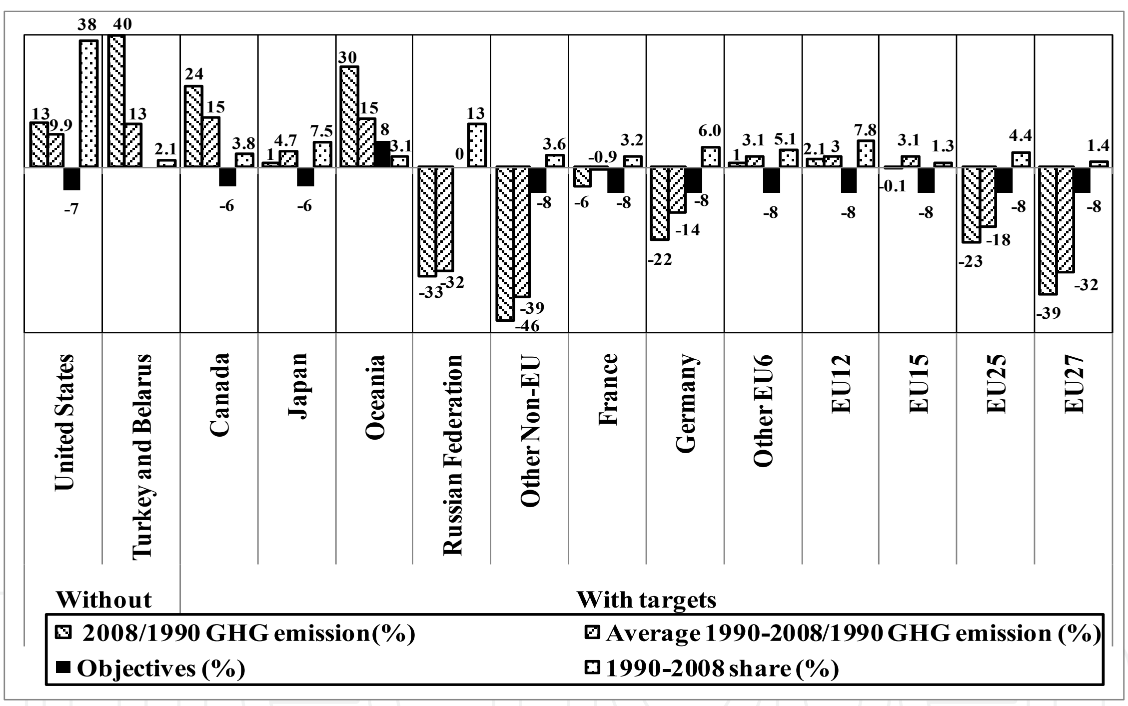

Fig. 2. Has the reduction targets been reached for Annex I countries? A direct ratio and cumulated ratio perspective

In this framework, as shown in **Figure 3a)**, the historical perspective of Russian federation emissions is straightforward: a huge decrease due to the former Soviet Union reconstruction until 1998 and a slow increase since then. The importance of the former Soviet Union reconstruction in the rapid decrease of European emissions is further confirmed by the profile of the evolution of German emissions[4]. Nevertheless, contrary to Russian federation,

[4] Indeed, the former DRG experienced a huge decrease of emission in the beginning of the nineties, 50% decrease in terms of CO_2 emission over the 1987 – 1993 period while the 1993 CO_2 emissions level of the former FRG is 2% more than 1987 level (United Nations, UNFCCC, 1994)

German decreasing emission trend has been going on after 1998 though at a slower pace. **Figure 3a)** allows a clearer distinction between Japan and Oceania historical evolution of emissions. While Oceania emissions are growing at a high rate especially in the 1995-2000 periods, Japan experienced their main rise in emission in the 1990-1994 periods before remaining around the same level until a huge drop in 2008 which may be due to financial crisis. Therefore, contrary to Oceania, Japan, though not fulfilling in 2008 its Kyoto target, seems to have at least stabilized its emissions. Finally, France, after some chaotic variation corresponding to the 1993-1994 recession period, experienced a slow decrease in its emissions between 1998 and 2005 followed by a higher decrease during the 2005-2008 periods. Interestingly, the beginning of this higher decrease period coincides with the introduction into the French V[th] republic constitution of an environment charter (Digithèque MJP) and the entry into force of the Kyoto Protocol. Since then, environment has taken a stronger place in French policy debate but it should be noted that in spite of these late efforts, France has not in 2008 met its Kyoto targets.

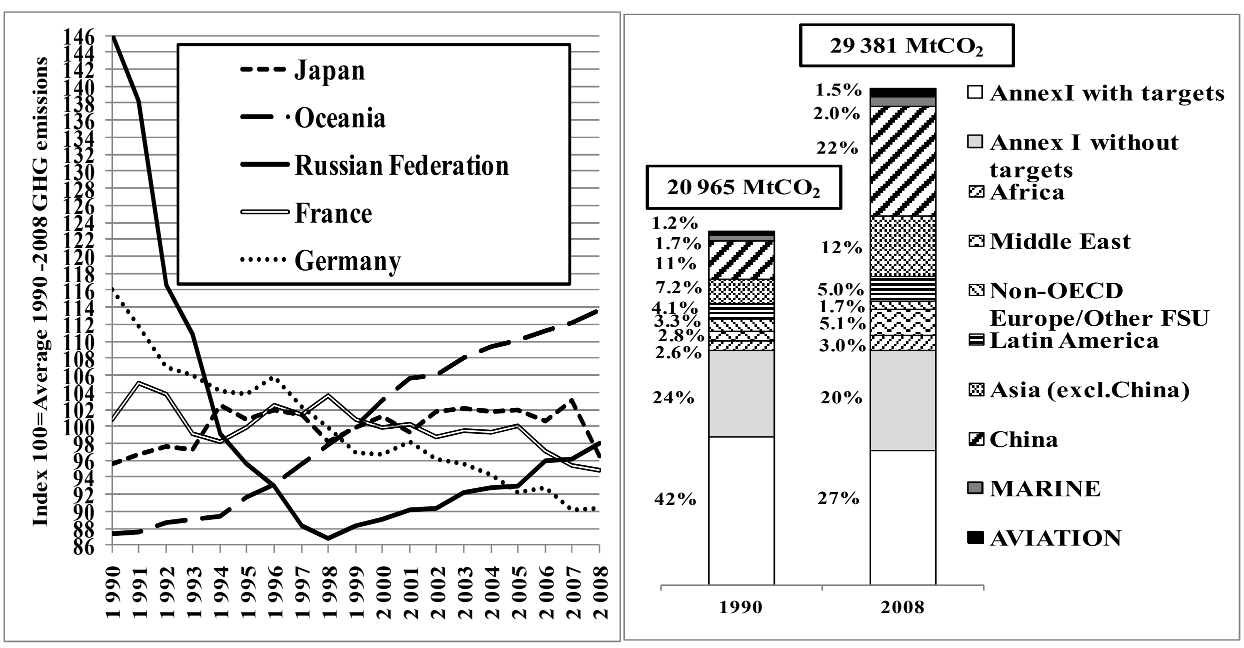

Fig. 3. a) A historical perspective of the evolution of GHG emissions compared to 2008 emission level.
b) Evolution of the structure worldwide energy-related emissions between 1990 and 2008

According to IEA report (IEA, 2010), the world carbon dioxide emissions associated with fuel combustion has increased by 40 percent during the period 1990 – 2008, from 21.0 $GtCO_2$ in 1990 to 29.4 $GtCO_2$ in 2008. During this period, the Annex I CO_2 emissions associated with fuel combustion has remained the same, thus showing the difficulties to implement CO_2 reduction when it comes to fuel combustion processes. Indeed, if the 2008 GHG emissions of Annex I countries are 5.2% less than those of 1990, their 2008 CO_2 emissions are only 2.2% less than those of 1990. This demonstrates that most of the GHG emission reduction achieved concerned GHGs other than CO_2 such as methane and nitrous oxide and that among CO_2 emission reduction, those concerning fuel combustion has particularly difficult to achieve. Furthermore, while Annex I countries represented 66% of world CO_2 emissions associated with fuel combustion in 1990, they represent only 47% of these in 2008.

Consequently, post-Kyoto policies must necessarily consider that more parties should get emission reduction targets and not only Annex I countries. As shown in **Figure 3b)**, Asian countries and particularly China should be among the first to get these emission reduction targets as their associated fuel combustion CO_2 emissions raised up from 19% of 1990 world emission to 34% of 2008 world emission. Indeed, when looking at the top20 CO_2 emitters in 2007, which alone cover 81% of the world CO_2 emissions, a worldwide pattern of CO_2 emissions clearly appear, Asia (35%), North America (23%), Europe (15%), Middle and Near Eastern countries (3.1%), Africa (1.5%), Oceania (1.3%) and South America (1.3%)[5]. Furthermore, among the top20 CO_2 emitters in 2007, Annex I countries represent 55% of the GHG emissions and only 30% if the United States who did not ratify the Kyoto protocol are taken out of Annex I countries emissions. Consequently, efficient post-Kyoto policies will have to deal with the increasing distribution of GHG emissions worldwide.

The globalization of trade and associated GHG emissions are logically connected to an increase of GHG emissions associated with international transportation. Actually, the 2008 CO_2 emission associated with international marine bunkers fuel combustion are 63% higher than those of 1990 while those of international aviation bunkers have increased by 76% over the same period. Moreover, transport represents 22% of world CO_2 emissions in 2008 thus constituting an important potential for mitigation policy. Nevertheless, global demand for transport appears unlikely to decrease in the foreseeable future as the *WEO 2009* projects that transport will grow by 45% by 2030(IEA, 2010). Noting that international bunkers emissions are not currently part of Kyoto protocol framework, the observed globalization of GHG emissions calls for the development of methodologies able to track down national and international bunkers emissions throughout the patterns of trade so as to ensure the best post-Kyoto GHG emission reduction international policy. However, current methodologies regarding GHG emission accounting framework mostly focus on national emission patterns and miss the trade perspective. Consequently, the next section presents the evolution of perspective required by the introduction of trade within the GHG emission accounting framework. Then section **2.3** focuses on the transportation aspects needed to frame a comprehensive macro-economic GHG emission accounting framework.

2.2 Production or consumption perspectives?

The GHG emission reduction targets of Annex I countries is based on a national GHG accounting framework which is thus production driven since all emissions resulting from national residents activities are assigned to the associated country. Particularly, this means that American companies, which are resident in France will contribute to French GHG emissions and not American ones. In the same perspective, French tourists visiting the United States contribute to American GHG emissions. This framework is thus in line with the Gross Domestic Product (GDP) framework which aggregates in monetary terms the results of residents' production but not with the Gross National Income (GNI) which would associate American companies in France with the United States.

[5] **Asia**: China (22%), India (5.5%), Japan* (4.3%), Republic of Korea (1.7%), Indonesia (1.4%) ; **Europe**: Russian Federation* (5.2%), Germany* (2.7%), United Kingdom* (1.8%), Italy* (1.6%), France* (1.3%), Spain* (1.2%), Ukraine* (1.1%) ; **North America**: United States* (20%), Canada* (1.9%), Mexico (1.6%) ; **Middle and Near Eastern countries**: Islamic republic of Iran (1.7%), Saudi Arabia (1.4%) ; **Africa**: South Africa (1.5%) ; **Oceania**: Australia* (1.3%) ; **South America**: Brazil (1.3%) ****Annex I countries***

The fact that GNI is generally different from GDP is a sign of the globalization process. However, even if imports and exports have roughly doubled between 2000 and 2009, the main contributing countries to globalization covering more than 50% of worldwide monetary exports and imports remain those of Western Europe, East Asia, and Northern America[1] thus creating three globalization driven attractive economic areas (dat). Nevertheless, the globalization process is still expanding and new globalization driven attractive economic areas will appear in the future. Notably, one of the consequences of this on-going process will result in an even more increasing inter-connection of countries GHG emissions than the one presented in section **2.1**. Consequently, two perspectives are offered to policy-makers:

- **The production perspective (PP)**: GHG emission reduction should be based on the amount produced by country as following the sovereignty principle, each state is the only one able to enforce emission reduction from its resident production activities. Therefore, the GHG emissions associated with the production perspective (**GHG_{PP}**) is the sum of GHG emissions associated with resident production activities for their own consumption (**GHG_C**) and those for exports (**GHG_E**).
- **The consumption perspective (CP)**: GHG emission reduction should be based on the amount consumed by country as following the sovereignty principle, each state is the only one able to enforce emission reduction from its resident consumption activities. Therefore, the GHG emissions associated with the consumption perspective (**GHG_{CP}**) is the sum of GHG emissions associated with resident production activities for their own consumption (**GHG_C**) and those associated with imports (**GHG_I**).

The difference between CP and PP results from the difference of GHG emissions embodied in exports and those embodied in imports. Therefore, while PP policy options only aims at improving national production GHG efficiency, CP policy options are dependent on the trade partners' production GHG efficiency. Consequently, the CP policy options would have to be more collaborative raising the issue of emission allocations between actors (Lenzen, et al., 2007).

For 2004, Davis and Caldeira determined that 23% of CO_2 worldwide emissions were traded internationally primarily as exports from china and other emerging markets to consumers in developed countries (Davis, et al., 2010). This result was further confirmed by Peters and Hertwich who determined that almost one-quarter of carbon dioxide emissions released to the atmosphere is emitted in the production of internationally traded goods and services (Peters, et al., 2008) thus calling for the introduction of trade within post-Kyoto policy debate (Peters, et al., 2008). Following this trade perspective at the Chinese national level, Ackerman determined that if Chinese exports and Chinese imports were produced with the U.S. carbon intensity, the CO_2 trade surplus would be close to zero as CO_2 emissions associated with Chinese exports would decreased by around 75%(Ackerman, 2009). Other studies regarding carbon embodied in trade were realized in developed countries[6]. All of these studies show as in **Figure 4** that CP leads to higher GHG emissions than PP for most of the developed Annex I countries.

On a policy level, this means the risk of carbon leakage is high as the developed countries could relocate GHG-intensive activities to a cheaper labor but less GHG efficient market and

[6] Austria (Kratena, et al., 2010), U.S (Weber, et al., 2007), France(Lenglart, et al., 2010)

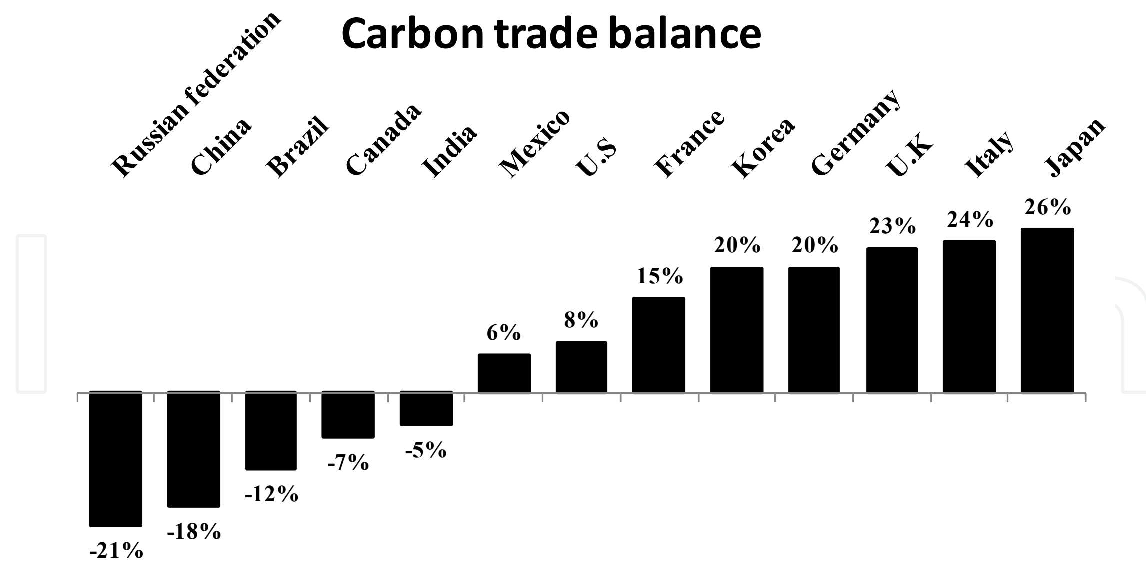

Fig. 4. Carbon trade balance for main GHG emitters' countries (Sustainable Consumption institute of the University of Manchester)

then import high GHG embodied goods, which are currently not accounted in the Kyoto framework. Therefore, it would be more politically sounded to evaluate CP emissions as it could help convince new emerging countries to join Annex I and get emission reduction targets. Furthermore, a comprehensive framework of the trade patterns is in line with the micro-economic perspective of life cycle assessment (LCA). Indeed, CP corresponds to the product perspective of carbon labeling policy, further explained in section **3.1**., and thus offers possibilities of bi or multi-lateral agreement between countries on the way to achieve reduction of GHG emissions for particular products or sectors.

Nevertheless, from a methodology perspective, CP is more data intensive than PP. Indeed, language, policy issues, non-recorded data, or data non-recorded at the same detailed level are examples of the barriers encountered to comprehensively associate data from trading countries. Furthermore, contrary to PP which only accounts in an aggregate way the national emissions, CP supposes to be able to track down imports, exports and production for national consumption separately thus raising the issue of data availability. Finally, though many environmental assessment methodologies are available such as material flow analysis (MFA), life cycle assessment (LCA) and input-output analysis (IOA) (Hertwich, 2005)(Wiedmann, et al., 2006), they do not cover the same perspectives. LCA and MFA are bottom-up approaches, consequently more suitable to micro-economic or company level, whereas IOA is a top-down approach more suitable to a macro-perspective. Particularly, multi-regional Input-Output analysis (MRIO) lies at the core of CP (Hertwich, et al., 2004), implemented in three ways depending on data availability:

- **The single region IO framework**: The analyst has been able to differentiate imports, exports, and national production for national consumption but has no data from other regions. A mirror-economy assumption is then used by giving the same economic structure and thus the same GHG efficiency to the trade partners which allows the distribution of GHG emissions to each import from and export to these countries. Nevertheless, the mirror economy assumption may be quite far from reality. Indeed, the carbon efficiency of economies may vary a lot between developed and developing countries but between developed countries. For example, the French electricity carbon content is cleaner than the German one.

- **The without re-import/re-export MRIO framework**: IO tables from other countries with the associated emissions are available but it is supposed that direct trade predominates. Thus, it is assumed the production of imports for one country does not induce production within this country.
- **The comprehensive MRIO framework**: IO tables from all countries with full differentiation between imports and domestic technology matrices are available. Therefore, a comprehensive multi-lateral trade analysis can be made. This framework is data intensive.

In PP, national transportation analysis is straightforward as it can be associated with a particular country. However, it should be noted the transport sector is often not well represented within the national accounting framework leading to the making of IO tables. Moreover, international transport appears difficult to analyze, as they constitute by their international nature a complex allocation problem. To adopt CP changes the way to deal with the transportation allocation problem. Indeed, in this perspective, transportation is seen as part of a product story of life cycle. Consequently, the associated emissions go to the country that consumes the transported goods. However, may it be CP or PP, there is a need for the development of methodologies that better integrate freight transportation. Section 2.3 provides an overview of the last researches done in this direction. Sections 3.1 and 3.2 respectively present the carbon labeling policy framework within which transportation takes its full meaning and the related allocation issues.

2.3 Towards a better integration of GHG emissions from freight transportation

The MRIO framework explained in **2.2** though enabling the tracking of emissions embodied in trade with technology differentiations between nations misses to specifically address freight transportation. However, transportation key role in global trade and associated GHG emissions have been increasing ever since 1990. Therefore, new models have been developed to specifically address the issues associated with freight transportation such as food-miles and the connection between product, location of production, choice of transport mode and GHG emissions. These models are based on the IO framework but further differentiate transportation by applying a vector characterizing the Ton-kilometers (Tkm) driven for each sector before calculating the GHG emission associated through the application of physical based sounded ratio such as gCO_2/Tkm ratios.

For example, Webers and Matthews applied a single region IO framework to the U.S. together with an extended transport model to determine the impacts of transportation within the supply chain of food products (Weber, et al., 2008). They found the food-miles problem, namely the trade-off between buying locally or globally, was less important in terms of GHG emissions than the shifting diet problem. Therefore, they confirm the predominance of production climate impact over transportation climate impact for food products. Notably, their study pointed out red meat products top scoring on climate impact is only third when it comes to transportation GHG emissions. Indeed, transportation emissions associated with red mead was found within the same range of fruits, vegetable, and cereals products.

In their study on greenhouse gas emissions driven by the transportation of goods associated with French household consumption, Hawkins and Dente constructed a without re-import/re-export two regional IO model extended with a transportation model accounting for 116 sectors, 175 product types, 5 transport modes, 22 French regions and 42 foreign countries (Hawkins, et al., 2010). The imports coming from the 42 foreign countries were assumed to be produced using German technology, as IO tables were not available at a sufficient level of details for all the 42 countries. It was found that French household consumption was responsible for the emissions of 627 $MtCO_2e$ in 2004, 54% more than the 2005 French territorial CO_2 emissions and 14% more than the total CO_2 emissions driven by total 2005 French final demand as determined by the French National Institute of Statistics and Economic Studies (INSEE) through a six regional classical IO model including Germany, Italy, Belgium, U.K. and Spain in addition to France. Nevertheless, the INSEE study provided low values for agriculture since only dealing with CO_2 emissions and not GHG emissions contrary to the Hawkins and Dente study which showed that when dealing with GHG emissions, the agriculture sector accounted for as much as 23% of production and transport related emissions (cf. **Figure 5**). This difference in scope explains most of the result differences observed between the two studies, the rest of the difference being explained through a number of factors: better representation of national and international transportation with the specific transportation model for the Hawkins and Dente study, better representation of the technology differentiation for the INSEE studies as more regional IO tables are taken into account. Furthermore, it is interesting to notice the Hawkins and Dente study estimated to $14MtCO_{2e}$ the transportation occurring abroad for the purpose of French household consumption.

The above examples shows the use of transport specific models allows for a better tracking of flows within the supply chain of global economies and better represents the patterns of trade and international transportation, the fundamental features of globalization. Moreover, coupled with comprehensive MRIO models, these models allow for differentiation between indirect and direct emissions, transport modes emissions, sector and product differentiations, linkages between the final demand and the CO_2 global economic chain. **Figure 5** provides a good description of the achievement available through the application of such models, which provide important analyses and indications for national and supra-national policies such as national emission reduction planning and the Kyoto Protocol.

However, the application of transportation model supposes not only to have data to lead a comprehensive MRIO framework but data from transport satellite accounts for all countries. Therefore, the main problem is data availability and initiatives are made notably at the European level through the EXIOPOL project to offer harmonized detailed IO tables for all the EU-27 members (htt4). In this perspective, it should not be forgotten that non-Annex I Kyoto parties were encouraged to establish statistical competencies for the evaluation of their GHG emissions (United Nations). Moreover, the gCO_2/tkm ratio taken within transportation models can vary greatly depending on the goods transported and the upstream logistic choices, which determined load factor and empty trips ratio. Thus, take an average cross-technological gCO_2/tkm ratio can lead to errors in the determination of emissions and data from meso/micro levels are needed to address the problem of the greening of global supply chains. These questions are the purpose of section 3.

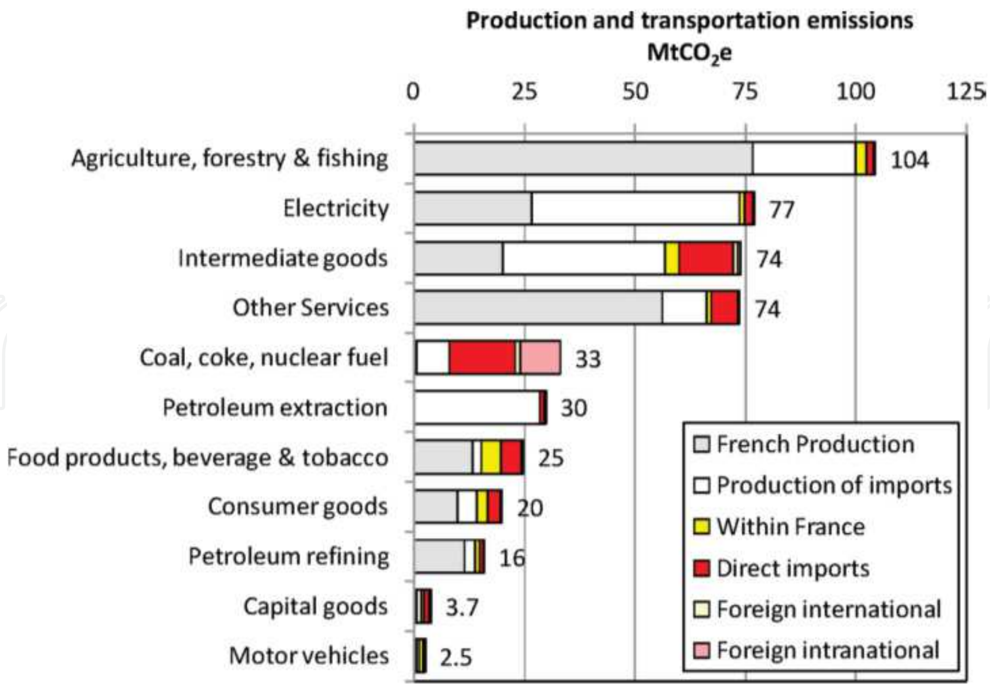

Fig. 5. Production and transportation emissions associated with French household consumption (Hawkins and Dente, 2010)

3. How to frame GHG reduction and ensure a greening of supply chains

3.1 The scientific, business and policy challenges of carbon labeling

At the most basic level carbon labeling involves associating an amount of CO_2 equivalent emissions with a product. Though seemingly simple in principle, carbon labeling schemes raise challenges upon application. These challenges make it difficult to standardize a method for quantifying CO2 equivalents for carbon labeling and open the possibility of litigation and controversy upon implementation.

Carbon labeling is closely tied to the complex relationship between companies, consumers, and policy makers. In section **2.2** we discussed two options for framing carbon labels, the producer perspective (PP) and the consumer perspective (CP). PP implies setting guidelines that move companies towards improving carbon efficiencies. These could take the form of thresholds, limitations, bans, externality-related taxation schemes, subsidies for cleaner production processes, and research efforts focused on improving or replacing dirty processes. CP shifts the focus to that of a consumer who is concerned with the overall impact of each product rather than the specific impacts of nodes in the supply network. In contrast to PP where policy actions focus on enhancing the carbon efficiency of individual actors or sectors based on their relevance to total territorial emissions, CP policy is focused on the community of actors involved in an individual product life cycle or basket of goods. From the perspective of a particular company, there are two strategic advantages to viewing their own environmental impacts from a consumer perspective and having policy-makers do so as well.

Quantifiable evidence of environmental performance is valued by customers:

Consumers choose products based on the information they receive. All else being equal, a consumer should choose the least costly option. However, the consumer's perception of characteristics such as quality, durability, aesthetics, others' perceptions, and a number of other factors combine with price in the final decision of which items to purchase. In the absence of reliable environmental information, as is the case today, it might appear that consumers do not factor the environmental impacts of production processes into purchasing decisions (Llerena, et al., 2007). However, as rigorous environmental indicators find their way into the marketplace, the willingness to pay for improvements in the life cycle environmental quality of products will increase as a result of consumers' desire to convey a positive image to others through their choices and perhaps through an internal desire to view themselves as altruistic. When confronted by otherwise equivalent products resulting from different production processes, a well-informed consumer would not be as indifferent as might be predicted by a narrow interpretation of traditional economic theory. Within a society whose environmental conscience is growing, as is the case today, companies that provide information about environmental performance, demonstrate transparency, and continue to improve win market share over time to those that do not.

The enhanced efficiency of supply chains:

The usual framework to analyze competitiveness is to compare the cost structure and competitive advantage of actors producing similar products with the goal of becoming more cost-efficient while maintaining customer satisfaction. In the current globalized world, this framework still holds true but has evolved from the company level to the supply chain level. Each actor of the supply chain contributes to the comparative advantage of the entire network leading to product sales. In such a complex system often, local optimization does not correspond with the optimization of the global system and can even result in worsening the previous situation. First generation biofuels and the replacement of lead solder exemplify how a narrow approach to the optimization can result in global worsening. While biofuels were seen as attractive replacements for fossil fuels because carbon uptake by plant biomass would off-set the releases upon combustion, further analysis suggests the combined impacts of inputs to agricultural production, soil carbon loss, and other factors may well drive an overall higher carbon footprint. In the case of solder, lead was replaced by costlier substitutes such as silver, with greater extraction- and processing-related impacts, and potentially the same or higher toxicity considering exposure routes along their supply chains. Although these examples are controversial and dependent on which factors are considered in the optimization, we present them here for illustrative purposes.

Although the scope of decision-making for a company lies within its own operations, considering each company relies on the supply network within which it exists, the consumer perspective better addresses overall competitive advantage. Furthermore, CP does not exclude improvements in the carbon efficiency of individual actors, but through the broader perspective, it deals with offers the possibility to transform the investments made in these improvements into market strengths.

In spite of the expected benefits from the implementation of CP for companies, most of the efforts so far have been policy driven. For example, the EU sustainable consumption and production, which includes eco-labeling, aims at reducing the negative impact of consumption on the environment, health, climate, and natural resources. On 24th November 2009, the European parliament resolved to widen the EU eco-label scope in terms of impacts and product categories to avoid the proliferation of environmental labeling schemes and to encourage improvement in all sectors for which environmental impact affects consumer choice

(Reg11). More recently in France, the Operational Committee on Consumption, Ecological Price and Competitive Advantage of the "Grenelle de l'environnement" announced that environmental information will be required for each product beginning 1st January 2011 (Ministère de l'Ecologie, du Développement durable, des transports et du logement). Though this goal is still in the process of being realized a proposition within the consumption code approved by the French Senate (Article 85) requires carbon cost labeling (htt1). This will be provided on an experimental basis beginning in July 2011 (Afnor-Normalisation).

To answer the raising environmental awareness of their consumers and the compulsory labeling policies driven by policy makers, businesses nevertheless took actions towards the reporting of their emissions, as the increasing number of carbon accounting tools tends to prove. An international benchmarking of carbon accounting tools realized by the French Environment and Energy Management Agency (ADEME) shows that this new market of environmental accounting tools concerns mainly Annex I countries of the Kyoto Protocol[7] and the United Nations Environmental Program (UNEP)(ADEME, 2008). On the 62 accounting tools reviewed, 10 are ONG's, 39 related to private businesses activities and 13 are governments'. Consequently, there is seemingly some serious environmental commitment from business companies. Nevertheless, while governments' and ONG's solutions are oriented towards emission reduction, a large majority of private accounting tools corresponds to the needs of companies to compensate emissions thus not enabling exhaustive emission accounting. Furthermore, most of the solutions are site and territory oriented since only ten of the accounting tools reviewed includes a product orientation. This demonstrates that today's accounting tools are in line with the policy framework developed by nations to achieve their Kyoto targets but are not sufficient to embrace the policy objectives of carbon labeling neither those of sustainable consumption. They lack interconnection with the different aspects of their activities to comprehensively accumulate emissions from each node of the supply chain and allocate them to the final consumer products.

However, ideally, the link between PP carbon accounting and CP carbon labeling is straightforward. Actually, let us assume that each company implied in the making and delivery of a product to the final retailer[8] is able to provide for each of their products the associated amount of CO_2 equivalent emitted. If we consider that N companies are implied in the making and delivery of product i and M as the total number of different products produced by these N companies, our previous assumption allows us to build a M times N dimension table (CO_2). Coefficient $\mathrm{CO}_{2_{i,j}}$ represents the amount of CO_2 equivalent associated with product i emitted by company j. In this mathematical framework, the PP carbon accounting framework appears as a sum across the rows $\left(\mathrm{CO}_{2,j}\right)$ while the CP carbon-labeling framework corresponds to a sum across the columns $\left(\mathrm{CO}_{2,i}\right)$.

$$CO_2 = \begin{pmatrix} \mathrm{CO}_{2_{1,1}} & \cdots & \mathrm{CO}_{2_{1,j}} & \cdots & \mathrm{CO}_{2_{1,N}} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathrm{CO}_{2_{i,1}} & \cdots & \mathrm{CO}_{2_{i,j}} & \cdots & \mathrm{CO}_{2_{i,N}} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathrm{CO}_{2_{M,1}} & \cdots & \mathrm{CO}_{2_{M,j}} & \cdots & \mathrm{CO}_{2_{M,N}} \end{pmatrix} \tag{1}$$

[7] France, Germany, U.K., Australia, U.S.A, Canada, Netherlands, Japan

[8] The final retailer constitutes the final place of purchase but not of consumption. This distinction is important for future researches on the subject.

$$CO_{2,i} = \sum_{j=1}^{N} CO_{2_{i,j}} \quad \text{and} \quad CO_{2,j} = \sum_{i=1}^{M} CO_{2_{i,j}} \tag{2}$$

However, the establishment of these coefficients is rarely straightforward. Consequently, one of the major scientific challenges concerning carbon labeling lies in the allocation issues that are associated with the determination of these coefficients. The main features of these allocation issues are presented and analyzed in the next section **3.2**.

3.2 The allocation issues of carbon labeling

3.2.1 The allocation issue within a company

The scope of decision-making for a company lies within its own operations such as the transformation of purchased products, the business travels, the storing of raw materials, work-in-progress and finished products, the lightning and daily management of buildings and so on. The first challenge to ensure good management of GHG emissions at the company level is thus to allocate GHG emissions to each operation. This is not easy as different levels of complexity are intertwined within companies:

- Physical complexity linked to the industrial processes. Process engineering and management of complex physical systems constitute the main features of this complexity.
- Management complexity linked to the company objectives. Depending on the company business model, the complexity of management deals with socio-economic and physical indicators.

Regarding physical complexity, a first option would be to provide a continuous measurement of the emissions on every workstation. This would mean that each work station provide measurement of GHG emissions while delivering its work. Such framework is thus heavily based on electronic devices. The fact that many Annex I countries[9] have started implementation projects of smart meters as home energy monitors exemplifies how measurement device constitutes the understanding basis of the energy use at consumers' home. Notably, the United Kingdom counts on smart meters to address the greening of everyday energy-consuming behaviors through the completion of the smart meter roll-out in 2019 (Beh11). Nevertheless, smart meters are electronic devices and therefore consume non-renewable resources such as minerals and imply high-energy intensive processes in their making. Consequently, a trade-off between the environmental benefits that could be gained from the use of smart meters with the environmental costs associated with their life cycle must be found. A good way of avoiding the use of measurement systems is to base the determination of GHG emissions on explanatory variables through the use of physical models. One of the main advantages of using physical models is to adopt better manageable variables. For example, knowing that 1 toe corresponds to 1616 kg of coal, a company can at the same time track down their coal purchase in tons and calculate the energy they will use when burning it. Therefore, through calculation, physical models allow to multiply the benefits associated with a particular measurement. Nevertheless, the emissions associated with physical models are often determined in standardized conditions that may reveal quite far from reality. For instance, combustion process is sensitive to the environment

[9] Italy, Japan, Canada, United Kingdom, United States, Australia, New Zealand, Netherlands, Spain, France, Ireland, Italy, Malta, Sweden, Finland, Norway (Sma11)

temperature pressure and air/gasoline ratio and consequently would need to be associated with real-time measurements. Therefore, an uncertainty is always attached to the use of a physical model so that two companies using the same physical model and reporting two different GHG emission factor within the uncertainty range should be considered as having the same emission factor. Furthermore, direct measurement of GHG emissions should be preferred in the case of highly variable physical phenomena for which physical model are difficult to implement.

The management complexity consists in the organization of industry activities, the daily management of tasks and business travels together with the choices of processes. These decisions influence a lot the GHG efficiency of a company. Therefore, the allocation issue consists here in associating emissions with decision-making processes and is dependent on the time-framework chosen for the analysis. Electricity gives a good illustration of this point. Indeed, if we consider real-time measurement, assuming that $\mathrm{CO2}_{\mathrm{k}}^{\mathrm{j}}$ is the per kWh emission factor determined for the power plant k based on primary energy source j, the carbon content of 1kWh delivered to the network is:

$$\mathrm{CO2}_{\mathrm{network}}(t) = \frac{\sum_{Network}\left(kWh_k^j(t) \times \mathrm{CO2}_{\mathrm{k}}^{\mathrm{j}}(\mathrm{t})\right)}{\sum_{Network} kWh_k^j(t)} \tag{3}$$

Getting the level of carbon emission at the yearly level would imply to sum the previous framework over time. In this ideal case, we thus obtained a comprehensive framework of emission per energy source with a timeline result. However, in present days, these kind of accurate data are not easily available. The electricity productions for each power plant are often given at the yearly level. Furthermore, there is often only a simple distinction of emission factors based on energy sources. The carbon content of 1 kWh delivered by the network is thus constant over the year:

$$\mathrm{CO2}_{\mathrm{network}}^{\mathrm{year}} = \frac{\sum_{Network}\left(kWh_k^{j,year} \times \mathrm{CO2}^{\mathrm{j,year}}\right)}{\sum_{Network} kWh_{k,year}^j} \tag{4}$$

The difference between (4) and (3) exemplifies how important the time-management framework chosen can influence a GHG analysis. Furthermore, one cannot differentiate electrons on the electric network and it is thus physically not possible to source the origin of electricity used on the network to a specific power plant. Therefore, no one on the network use cleaner energy than the other at a given time. The ways to get cleaner electricity delivered at one particular moment are thus:

- Replace old power plants by newer and more performing ones $\left(\mathrm{CO2}_{\mathrm{k}}^{\mathrm{j}}\right)$
- Improve the electricity transformation process based on primary source j $\left(\mathrm{CO2}_{\mathrm{k}}^{\mathrm{j}}\right)$
- Change the primary energy source structure of the electricity delivered to the network $\left(kWh_k^j\right)$

The example of electricity demonstrates the difficulty of an accurate calculation and allocation of GHG emissions. First in terms of physical complexity, there is a need for standardization of the assumptions used in physical models. The lack of standardization and the difference of scope between studies are indeed the main features of green washing. By green washing, we define any communication using abusively ecological argumentation

(Afnor Normalisation). The abusive character of green washing can be based on insufficient scientific methods in data collection, modeling, allocation methods, or the use of sounded GHG inventories outside their uncertainty ranges. All these issues can lead to the communication of wrong or not meaningful GHG emission figures. Furthermore, in addition to the previous difficulties in the determination of GHG emissions, the absence of transparency on the method used to calculate GHG emission is often the main obstacle to decide whether or not there is a risk of green washing. Therefore, the reproducibility of the calculation methodology is essential to provide a clear allocation of GHG emissions related to physically complex phenomena. Once the physical characteristics of GHG emissions allocation are solved, it becomes important to understand how to use this information to take decisions that enhance the carbon efficiency of the company and the supply chain within it exists. As said before, such decisions refer to management complexity, which is dependent on the number of actors involved in the decision-making process. Freight transportation is characterized by an important number of actors thus raising interesting allocation issues related to management complexity. Section **3.2.2** presents some of these aspects.

3.2.2 The allocation issues related to transportation

Transportation is a service allowing the physical connection between two companies through the moving of goods. It is thus characterized by a complex set of actors: 1st party logistic providers (shipper, consignee), 2nd party logistic providers (carriers), 3rd party logistic providers (freight forwarders), and 4th party logistics providers (consulting and IT activities). These actors may have different interests and may not search to optimize the same aspects of the transport chain. A good example is given in the railway sector.

- The shipper wants to optimize the delivery of the goods it provides in terms of cost, reliability, etc.
- The carrier wants to optimize the routing of all the goods received from different shippers to minimize costs such as fuel expenses.
- The owner of goods wagons wants the use optimization of his assets

Therefore, optimization trade-offs need to be found between these different perspectives. This would mean that all actors implied in the transportation process are willing to optimize the all process rather than the small part they are responsible for. This holds particularly true for the problem of empty trips, which correspond to the transport of empty wagons. This problem exists for the other transport mode such as road transportation where the term empty truck is used. Who should thus be responsible for the GHG emissions associated with empty trips?

One could take the position of the EcoTransIT world tool intended to be used by shippers that want to estimate the emissions associated with a particular transport activity or a set of different transport options: the shipper or freight owner takes responsibility for the vessel utilization factor that is averaged over the entire journey, from the starting point to the destination as well as the return trip or the entire loop respectively (Eco). This allocation process is coherent with an LCA perspective as it allows for the tracking of emission associated with a particular good. However, accuracy on the routing of empty wagons is difficult to achieve as no commercial contract is linked to the moving of empty wagons. Furthermore, the decision regarding the management of empty wagons concerns as well the initial shipper, the owner of the wagon and the carrier. The latter must not only take into account the needs of the initial shipper but those of the other shippers to whom the empty wagons will be sent to be loaded.

Such complex patterns would not be a significant problem regarding allocation of GHG emissions if the level of empty trip did not have such an important effect on the GHG emission level. Indeed, according to a Mc Kinnon study (ECTA, Responsible Care and Cefic, 2011), the gCO_2/tonne-km emission factor for a 40-44 tonne trucks running 50% of its km empty is between 61% and 87% higher than when there is no vehicle-km run empty. Therefore, in the context of a carbon pricing, such differences will directly result in economic opportunity or losses. The same types of problems are encountered in the international maritime transportation area where the interdependencies of actors are even more complex. Indeed, the diversity of countries involved and notably the possibility to endorse a flag of convenience makes the determination of responsibility utterly complex. The term flag of convenience describes the business practice of registering a merchant ship in a sovereign state different from that of the ship's owners. The main interest for doing so is to reduce operating costs or avoid the regulations, notably taxes and environmental regulations, of the owner's country. Nevertheless, this situation makes it difficult to identify the ship owner and enforce a fair environmental post-Kyoto policy based on the allocation of emissions to the ship owner's state.

4. Conclusion

The present chapter has demonstrated the importance of globalization in regards to climate change and the necessity to include the trade perspective to enforce effective post-Kyoto policies. Such macro-policy framework is highly based on a better description of the GHG emissions associated with national and international freight transportation. Furthermore, the chapter revealed the difficulties of allocation associated with current policies notably in multi-actors sectors such as those of transport and logistics. **Figure 6** represents the hierarchy between the different allocation schemes explained in this chapter through an improvement loop. Doing so allows a clearer understanding of the distinction between scientific and policy driven procedures of allocation while maintaining the link between them. This framework shows where the opportunity for new researches stand:

- Improvement of measurement systems.
- Improvement of physical models so as to better capture the reality of physical processes.
- Improvement of collaboration between economic actors for the determination of environmental and market efficient allocation rules.
- Change in economic accounting practices and trade pattern through the implementation of more environmentally friendly business models such as Product Service System.

The non-exhaustive list above offers a glimpse of the path towards more sustainable grounds for supply chains and society.

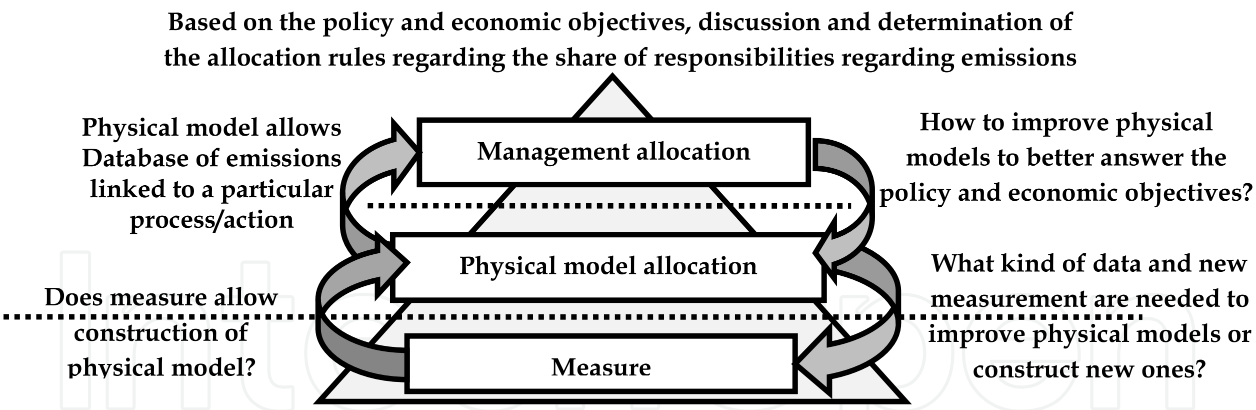

Fig. 6. The hierarchy between the different allocation steps and the on-going improvement process

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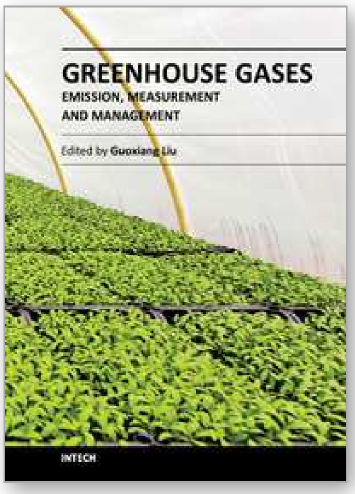

Greenhouse Gases - Emission, Measurement and Management

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Understanding greenhouse gas sources, emissions, measurements, and management is essential for capture, utilization, reduction, and storage of greenhouse gas, which plays a crucial role in issues such as global warming and climate change. Taking advantage of the authors' experience in greenhouse gases, this book discusses an overview of recently developed techniques, methods, and strategies: - A comprehensive source investigation of greenhouse gases that are emitted from hydrocarbon reservoirs, vehicle transportation, agricultural landscapes, farms, non-cattle confined buildings, and so on. - Recently developed detection and measurement techniques and methods such as photoacoustic spectroscopy, landfill-based carbon dioxide and methane measurement, and miniaturized mass spectrometer.