MATERIAL FLOW ACCOUNTING IN CHILE, ECUADOR, MEXICO AND PERU (1980-2000)

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Abstract

In this paper we compare the resource flows of Chile, Ecuador, Mexico and Peru between 1980 and 2000. In this time span, the domestic extraction of materials increased in the four countries, mainly due to the mining sector in Chile and Peru, biomass and oil in Ecuador and construction minerals in Mexico. Imports and exports increased too, due to the increasing integration in the international markets, prompted by the liberalization policies undertaken by the four countries between the late 1970s and the late 1990s. The four countries had a negative physical trade balance for most of the period analyzed, meaning that their exports exceeded their imports in terms of weight. However, the increase of imports reduced the physical deficit in Chile, Mexico and Peru. Ecuador's physical deficit was the highest and did not decrease in the period analyzed. Also, a diversification of exports away from bulk commodities could be observed in Chile and Mexico, and to a lesser extent in Peru, whereas in Ecuador the export sector remained mainly based on oil and biomass. More research is needed to explore the environmental effects of this phenomenon. Also, the indirect flows associated to the direct physical flows deserve to be subject to further analysis.

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1 Introduction

Between the late 1970s and the early 1990s, a set of neoliberal reforms was implemented in the majority of Latin American countries. The main axes of these reforms were privatization of public enterprises, reduction of public expenditure and progressive opening of the economy to foreign investment and international trade. These policies and their consequences have already been extensively analyzed using economic and social indicators (for example, Herzer and Nowak-Lehnmann, 2006, Cardenas, 1996; Pascó-Font, 2000). However, the effects on the biophysical dimension were mostly neglected by economists.

A particularly helpful methodology for investigating patterns of biophysical change is Material Flow Analysis (MFA), which assesses flows of materials through socio-economic systems. This methodology is based on the concept of *social metabolism* (Fischer-Kowalski, 1998b). According to this approach, an economy is seen as an organism, which extracts high quality materials and energy from the environment, processes them and then returns them back to the environment as low quality residues.

Material use is also regarded as an indirect measure of environmental impact (see, van der Voet et al., 2005). In fact, materials must be extracted and processed in order to produce goods that are then transported, exchanged, used and, finally, discharged. Environmental impacts are associated to all these activities.

MFA already has a long history (Fischer-Kowalski, 1998a; 1998b) and has been applied to most industrialized countries (Adriaanse et al., 1997; Matthews et al. 2000; Weisz et al., 2006). The MFA methodology was more recently used to discuss the biophysical

metabolism of some Latin American countries (Amann et al., 2002; Giljum, 2004; Gonzalez, 2007; Pérez-Rincón, 2006; Vallejo, 2006).

This paper provides a comparison of material flows in four Latin American countries: Chile, Ecuador, Mexico, and Peru. Our objective is to analyze the structure of societal metabolism of extractive countries and the consequences of neoliberal structural change on the use of natural resources.

Chilean, Ecuadorian and Mexican social metabolisms were analyzed thoroughly respectively in Giljum (2004), Vallejo (2006) and Gonzalez (2007). MFA indicators for these three countries were mainly built using information of national institutions and statistics. Where necessary, data sets were complemented with statistics from international organizations. The MFA dataset for Peru is based on international sources. The analyzed time span is 1980-2000, when important structural changes in the economies of these four countries took place (see Section 2).

All four country studies apply the EUROSTAT methodology for economy-wide MFA (EUROSTAT, 2001). The main material indicators used are:

- **Domestic Extraction (DE)**: Raw materials extracted within national borders.
- **Direct Material Input (DMI)**: **DMI = DE + imports**. DMI comprises all materials that enter the economy for further use, either in production or consumption processes.
- **Domestic Material Consumption (DMC): DMC= DMI - exports**. DMC provides information on the quantity of the materials that remain within the national territory.

It is important to underline that only inflows with an economic value were taken into account (*used flows*), leaving out the so-called *unused flows*, i.e. those flows that are not directly exchanged on the market but which are associated to the extraction of raw materials (e.g. overburden from mining processes).

The main material categories considered in this analytical framework are: biomass, fossil fuels and minerals. A fourth category, "other industrial products", comprises final goods that have not been included in one of the other material categories.

The paper is structured as follows. In Section 2 we provide an overview on the main physical, social and economic features of the four Latin American countries. In Section 3 we analyse material use in these four economies, putting special emphasis on physical trade balances. In Section 4 we illustrate the different material intensities of imports and exports. In Section 5 we provide a discussion of the results and draw our conclusions.

2 Countries overview

Table 1 gives an overview on the main structural indicators for the four Latin American countries and, as a comparison, EU-15, for the year 2000. Total area and population vary greatly among the four countries. Mexico is the largest and most populated country and Ecuador the smallest and least populated one. The four Latin American countries are by far less densely populated than Europe, as their geography includes large deserts, mountain ranges and tropical forests. Final energy use per capita is also much lower in the four analyzed countries than in the EU-15. European population uses on the average more than twice the energy used per capita in Chile (which has the highest energy use per capita among the four countries).

With regard to economic indicators, Mexico has the largest volume of economic activity, both in absolute and per capita terms. As a comparison, the income per capita in the EU-15 is much higher. As shown in Figure 1, when analysing the GDP per capita in Purchasing Power Parities (PPP), Chilean economy sky-rocketed in the period under analysis and surpassed the Mexican level from 1995. By 2000, the Chilean GDP per capita in PPP was the highest (9,115 US$), followed by Mexico (9,046 US$).

Another relevant feature of the four analyzed countries is the high income inequality: the richest 10% of the population hold between one third and one half of the total income in the four countries, while in Europe it only holds one fourth.

Year 2000	**Population**	**Population density**	**Area**	**Energy use per capita**	**GDP**	**GDP per capita**	**Income share held by highest 10%**
	Thousands	inhab/km^2	km^2	toe per capita	Million USD	USD/inhab	%
Chile	15,412	20.4	756,630	1.68	75,775	4,917	47.0%
Ecuador	12,306	43.4	283,560	0.68	15,942	1,295	41.6%
Mexico	97,966	50.0	1,958,200	1.53	581,426	5,935	41.7%
Peru	25,952	20.2	1,285,220	0.48	53,086	2,046	35.4%
EU-15*	376,462	116.1	3,242,601	3.90	7,965,639	21,159	25.2%

Table 1. Structural parameters, 2000

Source: World Bank (2007), (*) Eurostat (2002)

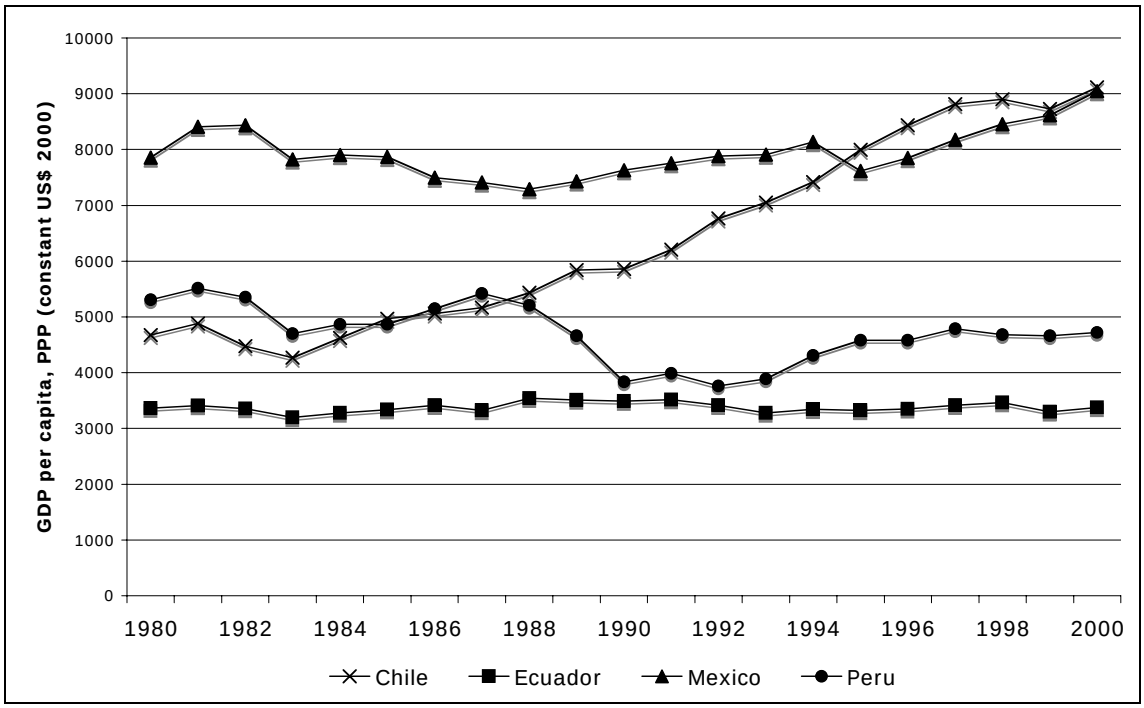


Figure 1 GDP per capita in PPP

As a result of a generalized economic crisis that took place in the 1980s, characterised by economic stagnation, high rates of inflation, net capital outflows and a huge external debt, important structural reforms were applied in Latin America. These reforms were imposed by the International Monetary Fund (IMF) and mainly consisted of a progressive opening of the economies to foreign capital and international trade and an increasing privatisation of crucial sectors, such as infrastructures, energy and education.

Chile was the first country in Latin America to adopt a market-oriented set of policy measures in 1974. The reforms deeply modified an economy which had been mainly based on import substitution and protectionism (the average tariff rate was almost 100 per cent). One of the main objectives of the military regime was to fuel economic growth through an increase in exports, stimulated by a strong devaluation and a drastic reduction of trade tariffs. Earnings from exports rose and also a diversification of exports took place: the relative importance of copper as the main export product decreased

from 80% to 40% between 1973 and 2000. In the 1990s, several free trade agreements were signed, including those with Canada, the United States, Central American and Mercosur countries.

After Chile's reforms began some years later to bear fruit in terms of economic growth, neoliberal policies were fully embraced also by other Latin America countries. Mexico, after a period of devaluation, hyperinflation and economic collapse (-0.6% GDP growth rate in 1982 and an additional -4.2% in 1983), implemented a neoliberal economic programme in 1988. Already in 1986, Mexico inaugurated a set of policies aiming at stimulating free trade by joining GATT (the General Agreement on Tariffs and Trade). Since then, it signed 12 trade agreements with 43 nations putting 90% of its trade under free trade regulations. The most important trade agreement has been the one signed with the United States and Canada (NAFTA), with trade tripling in monetary terms since NAFTA was ratified in 1994. Almost 85% of Mexico's exports are delivered to the United States, making the Mexican economy highly dependent on the economic cycles in the USA.

In Peru, president Fujimori introduced a neoliberal reform package in order to face the economic crisis of 1988-90, when GDP decreased by 20% (partly because of internal armed unrest) and the inflation rate was more than 7,000% (Diaz et al, 2000). The trade reform, which began in 1990, gradually reduced import tariffs. Also, the export sector was promoted through elimination of export tariff duties. As a result, exports grew in money terms by 80% between 1990 and 1997.

In Ecuador, market-oriented reforms were implemented late in 1992 with the so-called Stabilization Plan, which restructured the economy towards liberalization of trade and capital flows. During the 1980s, adjustment policies were focused on short-term stabilization rather than structural change (Vos, 2000), which in Ecuador has not gone

very far. In 1989, inflation reached historical rates (75%) and fiscal and current accounts were registering high deficits, which the government tried to reduce by means of stabilisation reforms.

3 Resource use in Chile, Ecuador, Mexico and Peru

The main material flow based indicators are displayed in Table 2. With more than 46 tonnes in 2000, per capita material input in Chile is one of the highest in the world (see Behrens et al., in press). For instance, in Finland, the country with the highest DMI per capita in Europe, in the same year DMI was 42 tonnes (EUROSTAT, 2002). Ecuador shows the lowest indicators, while Peru and Mexico are situated in between. In the rest of this section, material flow indicators for the four countries are analysed in detail.

	Domestic Extraction (DE)		Imports		Domestic Material Input (DMI)		Exports		Domestic Material Consumption (DMC)	
	1980	2000	1980	2000	1980	2000	1980	2000	1980	2000
Chile	16.0	44.6	0.7	1.7	16.7	46.3	1.2	1.8	15.5	44.5
Ecuador	6.8	6.9	0.3	0.3	7.2	7.3	1.1	1.6	6.1	5.6
Mexico	10.2	11.4	0.6	2.6	10.8	14.0	1.2	1.6	9.6	12.3
Peru	11.4	15.6	0.2	0.5	11.6	16.0	0.6	0.5	11.0	15.5
EU-15 *	13.8	13.0	3.1	3.8	16.9	16.8	0.8	1.1	16.1	15.6

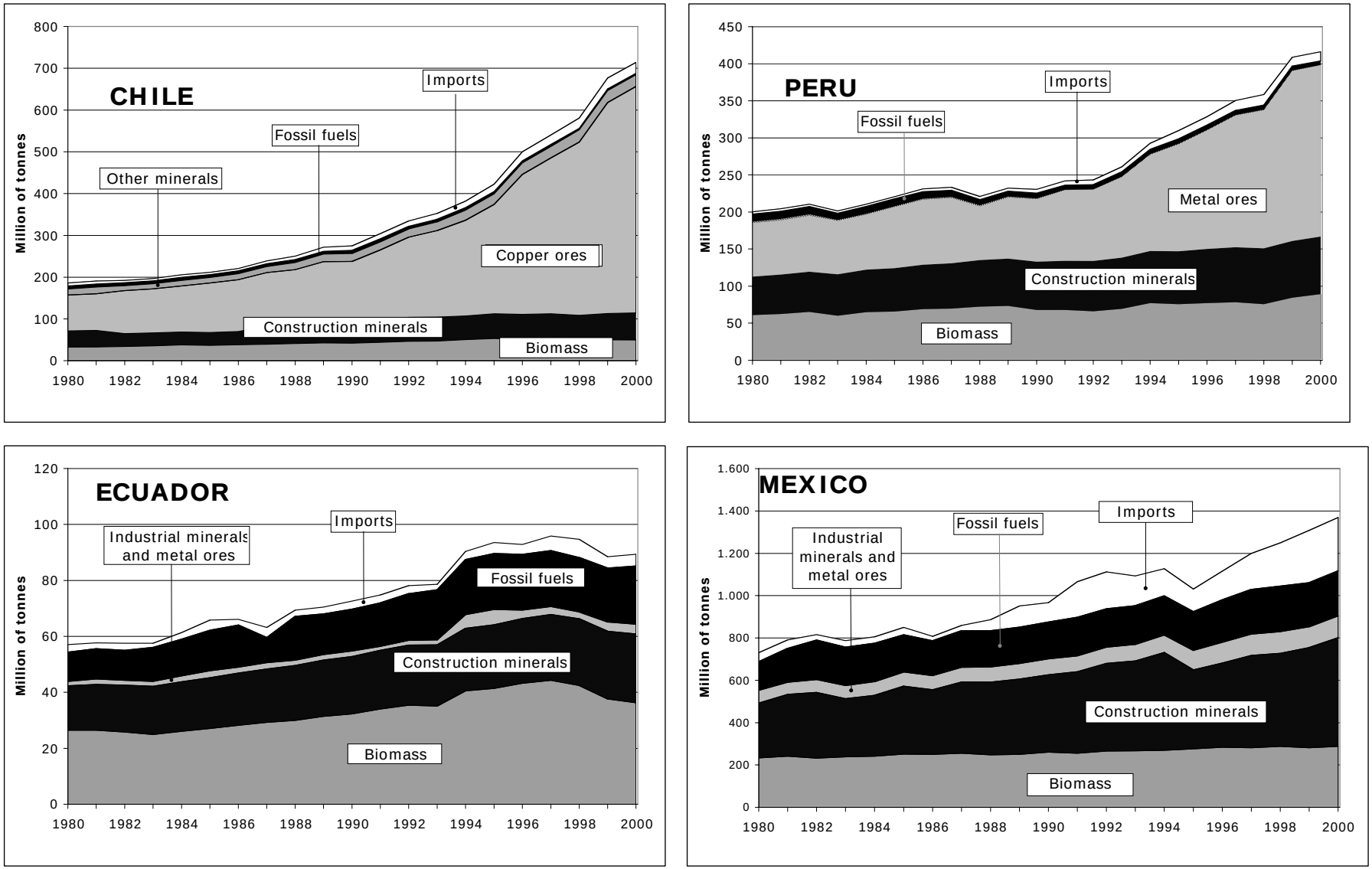
Table 2 Material flow indicators, 2000 (tonnes per capita)

(*) Eurostat (2002)

3.1 Direct Material Input

Figure 2 shows the Direct Material Input (DMI) of the four countries, with breakdowns by type of material flow. DMI includes all materials of economic value entering the economy and is obtained by adding up domestic extraction and imports. The DMI of all four countries increased between 1980 and 2000, although at very different rates. Most of the increase was due to intensified domestic extraction, while imports provided a growing but still small share (with the exception of Ecuador, where the import share did not increase in twenty years).

Figure 2. Direct Material Input in Chile, Ecuador, Mexico and Peru, 1980-2000



The Chilean DMI rose from 186 million tonnes in 1980 to 700 million tonnes in 2000. The main factor to explain this trend is the high rate of metal ore extraction (in particular, copper), which increased by 358%. In 1980, ores represented 50% of DMI while in 2000 their share rose to 78%. Construction minerals rank second (9%), followed by biomass (7%).

The Peruvian DMI increased at a low rate between 1980 and 1992 because of severe economic recession. After 1993, the slope of DMI was steeper, as a consequence of President Fujimori´s neoliberal policies and the end of the armed unrest in 1992. Like Chile, Peru is an economy based on mineral extraction (Kuramoto and Glave, 2002). Material input in Peru mainly comprises domestic extraction of metal ores such as gold, silver, copper, zinc and lead. The ore extraction share of DMI increased from 30% in 1980 to 55% in 2000 (the accumulated growth rate was 145%).

Ecuador has negligible metal ore production but it is a substantial exporter of oil (23% of DMI in 2000). In terms of weight, the Ecuadorian economy is above all based on biomass (mainly bananas and sugar cane), which accounted for 43% of DMI in 2000 (accumulated growth rate was 37%). The second main flow was construction minerals (28%), followed by fossil fuels (23%). The imports share of Ecuadorian DMI is very small.

Among the four analyzed countries, Mexico is the economy with the highest DMI, due to its larger territory and population. Between 1980 and 2000 DMI increased unevenly, although the general trend was upwards. A different DMI composition is observed if compared to the other three countries: construction minerals are the main material flow (42% share of DMI in 2000) followed by biomass (24%), which mainly consisted of animal fodder. Fossil fuels rank third (18%). In addition, Mexico shows the highest imports share in DMI, which

considerably increased in the period under analysis as a result of trade liberalization.

3.2 Trade balances

In the MFA method, the physical trade balance (PTB) is the most widely used indicator to analyze biophysical aspects of international trade. The PTB is calculated as the inverse of the monetary trade balance, i.e. by subtracting exports from imports. In the PTB, we only included direct flows, i.e. direct weight of imports and exports. A summary of the data referring to international trade is presented in Table 3.

	Imports (tonnes) 1980	Exports (tonnes) 1980	Imports of goods ($) 1980 (*)	Exports of goods ($) 1980 (*)	Imports (tonnes) 2000	Exports (tonnes) 2000	Imports of goods ($) 2000 (*)	Exports of goods ($) 2000 (*)
Ecuador	0.3	1.1	283	312	0.3	1.6	280	392
Peru	0.2	0.6	149	191	0.5	0.5	286	265
Chile	0.7	1.2	458	410	1.7	1.8	1,078	1,182
Mexico	0.6	1.2	290	229	2.6	1.6	1,780	1,696
EU-15 (**)	3.1	0.8	(-)	(-)	3.8	1.1	5,833 (+)	5,926 (+)

Table 3 Physical and monetary trade per capita, 1980 and 2000

(*) source: UN Comtrade, 2007 (**) source: Eurostat, 2002. (+) source: Eurostat Comext data-base. (-) data not available

As it can be observed in the table, the physical trade balance of the four countries was in deficit since 1980, meaning that more natural resources were exported than imported. As a consequence of the

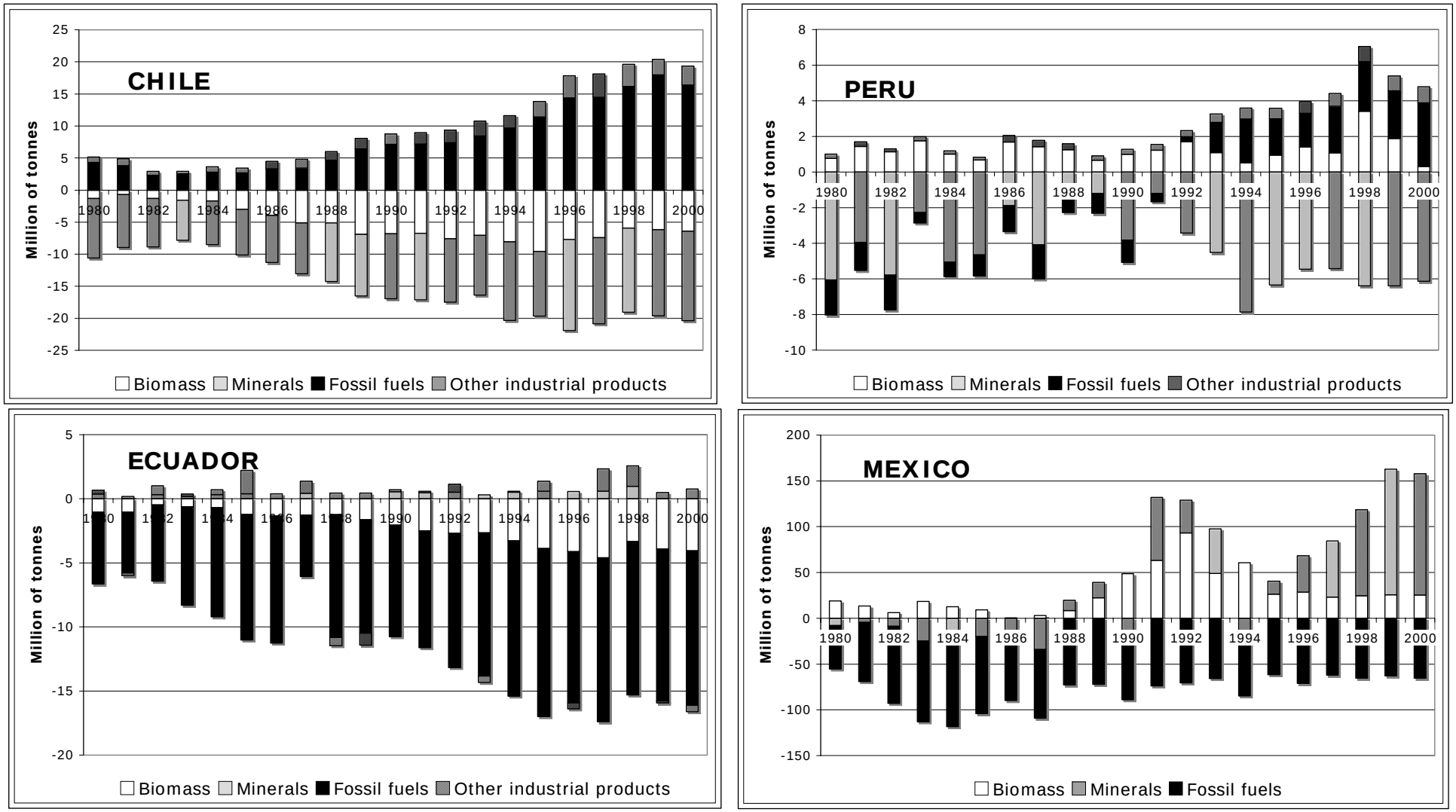
liberalization policies and the opening of the domestic economy, the four countries became increasingly integrated in international trade between 1980 and 2000. In particular, imports per capita increased more than exports in Peru, Chile and Mexico, whereas in Ecuador the reverse trend occurred.

It is interesting to note that also in the EU-15, development took an opposite direction, with imports per capita almost three times higher in terms of weight than exports per capita. European imports per capita were already 4 to 16 times higher than those of the four analyzed countries in 1980, and the difference increased in the following years, leading to an increasingly positive physical trade balance.

Figure 3 shows the PTB of the four countries in absolute terms, disaggregated in the four macro-categories: biomass, minerals, fossil fuels and other industrial products.

The PTBs of Chile, Peru and Ecuador were negative for most of the analyzed years. However, in Chile and Peru imports grew faster than exports, and the PTB constantly increased from 1994, despite remaining negative most of the time. On the contrary, in Ecuador exports grew faster than imports, leading to a negative and deteriorating PTB. Increase in imports was particularly dramatic in Mexico, with the consequence that its physical trade balance was positive in the last decade (with the exception of the years between 1994 and 1996, when a severe crisis abruptly reduced the imports).

Figure 3: Composition of the physical trade balance of Chile, Ecuador, Mexico and Peru,1980-2000



Chile was and is a significant net exporter of minerals and biomass. In Chile, even though the government carried out a policy of diversification of exports, in 2000 exports were still largely dominated by copper and other mining products (52% in terms of weight). Another 37% of Chilean trade in terms of weight was made up of biomass and biomass products. In addition a dramatic increase in net fossil fuel imports can be observed, driven by the high economic growth. As a consequence, fossil fuels were the most important imports in terms of weight (70% in 2000). In Chile a rapid reduction of the physical deficit can be observed from 1994, leading even to a positive PTB in 1998 and 1999. However, it must be noted that this picture would change, if the so-called indirect material flows of exports were also considered. Several studies of Chile's external trade (Giljum, 2004; Munoz, 2005) illustrate that in particular the production of concentrated metals requires huge amounts of primary materials and processing energy. As a consequence, waste and emissions related to the production of exports remain in Chile, while the refined products are exported.

Peru was a net exporter of minerals during the whole time span and a net importer of biomass. Also, it is interesting to note that at the beginning of the 1990s, Peru turned from a net oil exporter to a net oil importer. In Peru, in 2000 55% of exports in terms of weight consisted of minerals and ores (27% were iron ores and concentrates), 18% of fossil fuels and 27% of biomass (mainly feedstuff). In the same year, imports were mainly composed of fossil fuels (49%) and biomass (33%, mainly wheat and flour). Like in Chile, a reduction of the physical deficit can be observed in Peru from 1994. In fact, between 1980 and 2000 Peruvian imports increased from 3.0 to 12.2 million tonnes and exports from 10.0 to 13.5.

The Ecuadorian high and increasing material deficit is due to the increasing oil exports. Also, Ecuador was a net biomass exporter for

the entire period. In Ecuador, in 2000 fossil fuel products accounted for 60% of total exports in terms of weight, and agricultural and fishery products accounted for 24% thereof, whereas imports were dominated by industrial products (64%). Even though Ecuador is by far the smallest among the four analyzed countries both in terms of territory and population (see Table 1), already since 1988 its physical deficit was the highest among the four countries.

Mexico was a net exporter of fossil fuels and a net importer of biomass and metallic final products (included in the minerals category). In 2000, 58% of its exports in weight were represented by oil, 16% by non-metallic materials including construction materials and 10% by biomass. Imports were constituted by 56% by finished products - including the assembly parts for the “maquila” industry - and by 12% by fossil fuels, mainly in the forms of refined oil and basic petrochemical products.

Since the early 1990s the net exports of minerals rose considerably, due in part to the maquila industry. The “maquila” industry consists of assembly plants that use imported foreign parts and semi-finished products to manufacture final products for export, taking advantage of the large domestic pool of cheap labour. Although this type of industry came about at the end of the sixties in Mexico, it was not until the nineties that it experienced an important growth, gaining relevance in the Mexican economy (Carrillo and de la O, 2003). The components that enter Mexican borders to be assembled in the maquila industries are accounted for as inputs, and give a decisive contribution to the remarkable increase in imports. However, it should be noted that these material flows do not really have a proportional effect on the Mexican income, because the gain in added value is mostly transferred to the international headquarters of the companies.

The Mexican economy is different from the other three countries that we analyze in this paper. The relative dependence of the Mexican economy from exports of raw materials in the monetary trade balance decreased in the analyzed period (even though exports of raw materials increased in absolute values). Consequently, from 1992 to 2000, the Mexican PTB was positive. This can be explained by the "hybrid" nature of Mexico, whose pattern of development places it between that of a typical Latin American economy (characterized by low GPD and abundance of natural resources) [1] and that of industrialized countries (based on strong industrial and service sectors and a high dependence on imports for mineral ores, raw materials and fossil fuels).

3.3 Domestic Material Consumption and resource intensity

Domestic Material Consumption (DMC) provides information about the quantity of materials that remain within the national territory. It is calculated by subtracting direct physical exports from Direct Material Input (DMI). Considering that the materials accumulated will turn into emissions and waste at some point in the future, DMC has recently been proposed as an indicator of *potential waste* (Weisz et al., 2006).

DMC per capita in the four countries increased between 1980 and 2000 (see Table 2). In particular, Chile was characterized by the highest DMC per capita already in 1980 (15.5 tonnes), when it was close to the EU-15 average. By 2000 it increased by a factor of three. On the contrary, Ecuador had the lowest DMC in 1980 (6.1 tonnes), and by 2000 it decreased to 5.6 tonnes.

[1] Mexico, despite the economic fluctuations, reached a certain level of industrialization and is nowadays considered as an *advanced middle income country*.

DMC per capita can give misleading indications on the level of material consumption per inhabitant, particularly in economies based on mineral extraction like those of Chile and Peru. In fact, in these economies an important share of DMI ends up as waste of the mineral industry. For instance, this is the case in Chile, where copper (which represents a large share of domestic extraction) is represented as copper-containing mineral (run-of-mine with a copper grade of around 1%), whereas highly concentrated copper is exported. Therefore, large quantities of ancillary copper mineral – that part of the used extraction that ends up as waste along the concentration process – remains within the Chilean borders and is part of the DMC, but is only "consumed" by the Chilean mineral industry. Giljum (2004) showed that if the quantity of ancillary copper minerals is subtracted from DMI, the remaining material consumption actually grew at a very slow rate.

Relating DMC to GDP gives insight on the resource intensity of an economy. Two different trends can be observed (see Figure 4). On the one side the economies based on mineral extraction use a great deal of materials per unit of GDP – in 2000 Chile required 9 kg of matter to produce one dollar of GDP and Peru nearly 8 kg. On the other side, the material intensity of Ecuador and Mexico remained constant, although at different levels, i.e. 2 kg/US$ for Mexico and 4kg/US$ for Ecuador. Mexico is the most material-efficient among the four analysed countries. Nevertheless, the four countries are by far above the EU-15 material-efficiency level, which was 1.2 kg and 0.8 kg in 1980 and 2000, respectively.

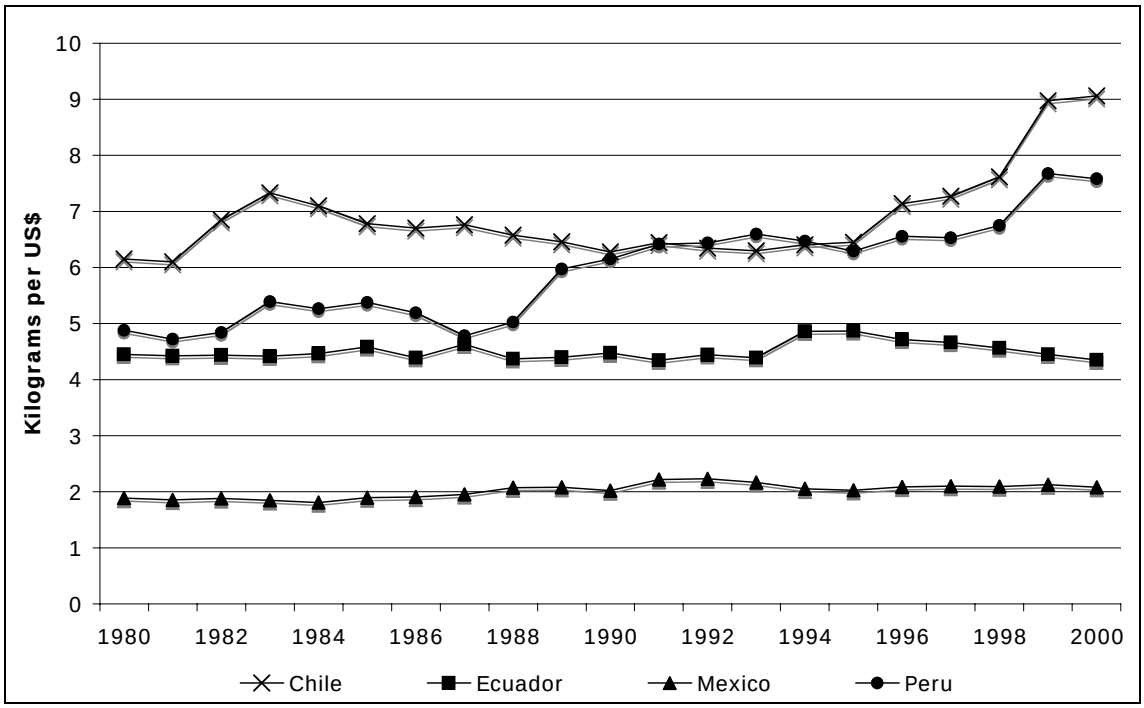


Figure 4 Resource efficiency in Chile, Ecuador, Mexico and Peru

Thus, Chile and Peru were characterized by a "re-materialization" process, and both showed an upwards trend in their material intensity curves. Peru in particular, increased its material intensity importantly catching up with Chile in the 1990ies. This trend was due to the highly material intensive mining activities. This phenomenon becomes more evident once the mining extraction is excluded from the MFA calculations. In the case of Chile, Giljum (2004) showed a relative delinking of economic growth from resource use for all sectors except copper mining. In the case of Peru, once the metal ores are excluded, DMC per capita remains almost constant over the period (3 tonnes in 1980 and 3.2 tonnes in 2000).

As for Mexico, despite the structural change and the increasing importance of industrial products, the material intensity did not decrease in the period 1980-2000. This may be due to the fact that only some specific sectors such as the electronic and the automotive

industries went through a process of technological change, while the rest of the sectors did not reduce their material intensity.

However, in order to have a complete picture of the overall material intensity of an economy, the unused material flows should be solidly measured and included in the analysis.

4 Material intensities of imports and exports

Although the PTBs (imports minus exports) of the four countries were mainly negative, the difference between imports and exports in monetary terms did not follow the same pattern. Chilean monetary trade balance (MTB; exports minus imports) was positive until 1992 and fluctuated thereafter, mainly due to price changes on raw material markets and increasing expenditures on fossil fuel imports. Ecuadorian MTB was mainly positive during the analyzed period due to the high oil exports (MTB was negative during the entire period with the exception of 1999, excluding the contribution of oil). Peruvian and Mexican MTBs were mainly negative in the 1990s, due to the increasing imports of finished and semi processed products, and also oil for Peru.

Figure 5 compares the prices per ton of imports and exports in 1980 and 2000. In 1980, the price per tonne of imports was considerably higher than the one for exports for all four countries. However, this difference decreased in the analyzed period in Mexico, Peru and Chile, with the price of exports increasing faster than the price of imports. Still, in 2000, the price of one average tonne of imports was 345%, 120%, 95% and 66% higher than the price of one average tonne of exports in Ecuador, Peru, Chile and Mexico. The case of Mexico is particularly remarkable, with the ratio increasing from 198 to 1046 $/tonne of exports. This is mainly due to the structural changes and diversification of exports, which significantly increased the share of

industrial products in total exports (from 4% to 59% in monetary terms). The maquila industry played a key role in this process. In fact, in 2000 according to foreign trade statistics (BANCOMEXT, 2004) the maquila share of exports was 47.7% of the total Mexican exports and 35.3% of the total Mexican imports in monetary terms, the latter including raw materials and semi-manufactured products for further processing and assembly.

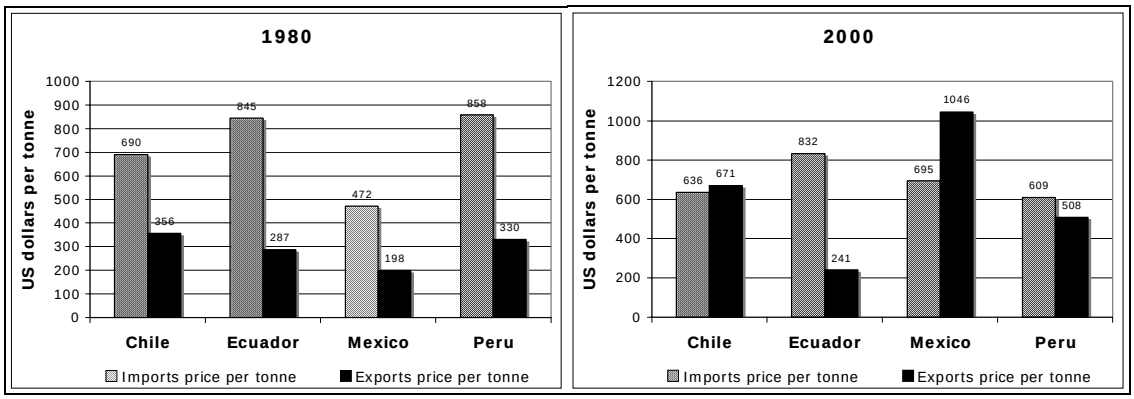


Figure 5 Price of imports and exports (current US$/tonne), 1980 and 2000

It is interesting to compare these Latin American data with European trends, where a reverse situation can be observed. In 2000, the EU-15 imported 3.4 times more materials than it exported, whereas the monetary trade balance was approximately balanced (Eurostat, 2002). Also, the average price for an imported tonne (1,559$/t in 2000) was about one third of the price for an exported tonne (5,306$/t), both numbers being significantly higher than those for Latin America. This reflects the position of this industrialised region in the upper value added segment of world markets.

For Latin American countries, the relative prices of the commodities exchanged on international markets determine that the contribution

of raw materials to the generation of added value is remarkably lower than their share in weight. In fact, the commonly observed pattern is that primary activities such as agriculture, forestry and mining extract large amounts of materials to obtain little added value. The mining sector's share of GDP in Chile is 8% (Banco Central de Chile, 2007) and in Peru it was only 4.5% in 2000 (Peruvian Ministry of Energy and Mining, 2004). In Mexico, the importance of resource-extraction-based activities in the production of added value is very small: the share of the whole oil sector (comprising oil extraction, refining and basic petrochemical) of the national GDP was only 1.3% in 2000 (INEGI, 2007). In Ecuador, the biomass-related activities (agriculture, fishing, forestry) accounted for 10% of GDP on average. Only banana production accounted for a comparatively large 2% of GDP. Fossil fuels, a strategic material flow in the Ecuadorian economy, provided only 13% of added value.

5 Discussion and conclusions

In this paper we compared trends in natural resource use in four Latin American countries, i.e. Chile, Ecuador, Mexico and Peru, between 1980 and 2000. The study of material flows sheds light on the biophysical metabolism of a society, a system open to the input of different materials and energy and to the output of waste, emissions and dissipated heat. By comparing economies in terms of material flows we have been able to identify characteristic structures and trends.

In the analyzed period, domestic material extraction increased constantly in all four countries. The important role of the mining sector in the economies of Chile and Peru and the role of biomass and oil extraction in Ecuador appears very clearly in the physical accounts. Similarly, although Mexico is an important oil exporter, material flow

analysis reveals the very relevant role of construction materials for this country.

In the case of Chile and Mexico, and even Peru, there was a diversification of exports away from bulk commodities, which increased the added value (and the price) per tonne of exported product. This development can be regarded as positive from a development point of view, as more added value is created within the domestic economy. The environmental implications, on the other hand, largely depend on the applied production technologies and the environmental regulations in place. If produced with high environmental standards, then such a development path could be both economically and environmentally rewarding. However, diversification of exports can also be a blessing in disguise, when considering for example the pollution and health hazards deriving from the maquila industry in Mexico (Carrillo and Schatan, 2005).

In addition, material flows have an effect on the social reality of environmental conflicts. True, Chilean copper mining takes place in largely uninhabited regions, while in Peru there are many mining conflicts due to the proximity to populated areas, pollution and use of scarce water. In Mexico and Ecuador, there are complaints because of environmental liabilities of oil extraction in some regions. The distinction between “preciosities” (high economic value per unit of weight) and “bulk commodities” introduced by Wallerstein (2007) is relevant here. Conflicts might arise against gold mining, as in the case of the successful resistance in Tambogrande (Piura, Peru) because of the threats of local pollution. However, for the importing countries’ metabolism, gold imports matter little - as compared for instance to oil or copper.

There has been a long discussion in Latin America about the negative consequences of exports of raw materials for economic growth. This

is very much present in popular awareness (Galeano, 1971). Along the same lines Sachs and Warner (2001) created the phrase of the "curse of natural resources", i.e. the fact that abundance of natural resources is often negatively correlated with economic growth. This holds for Ecuador for the whole time period and for Peru in the 1980s, but it does not apply to Chile and Mexico. The economy of Chile could instead be regarded as a successful example of the "staple theory of growth" (attributed to the Canadian economic historian Harold Innis), at least as long as copper reserves of good quality can be exploited and copper prices on world markets remain high.

MFA indicators shed light on the discussion of "deterioration of terms of trade" coined by the Argentinean economist Raul Prebisch (1952). His idea was that a unit of exports allows peripheral (extractive) countries to purchase lower and lower amounts of imports, leading to the vicious circle requiring increased amounts of commodity exports. This phenomenon may apply to some Latin American countries (see for example Pérez-Rincón, 2006, for a recent study on Colombia). According to our results, this theory applied in the eighties when the price per imported tonne was much higher than the price per exported tonne. However, in the year 2000, this pattern changed in some countries, with the difference between the price per tonne of imports and exports decreasing in Chile, Mexico and Peru. On the contrary, the Prebisch's theory still held for Ecuador, with its main focus on oil and biomass products.

One main and obvious conclusion is that the economies under consideration are certainly not on a path towards dematerialization. Further research is needed to investigate to what extent the re-location of resource-intensive productions outside the borders of industrialized countries is at the roots of the relative dematerialization process (decrease of the relation between use of materials and GDP) taking place in many European countries (Adriansee et al., 1997,

Weisz et al., 2006), as claimed for example by Rothman (1998). From this point of view, a careful and comprehensive analysis of the indirect flows associated with imports and exports is required, in order to attribute to the final consumers *all* natural resources required in the entire production chain (Weisz, 2007).

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