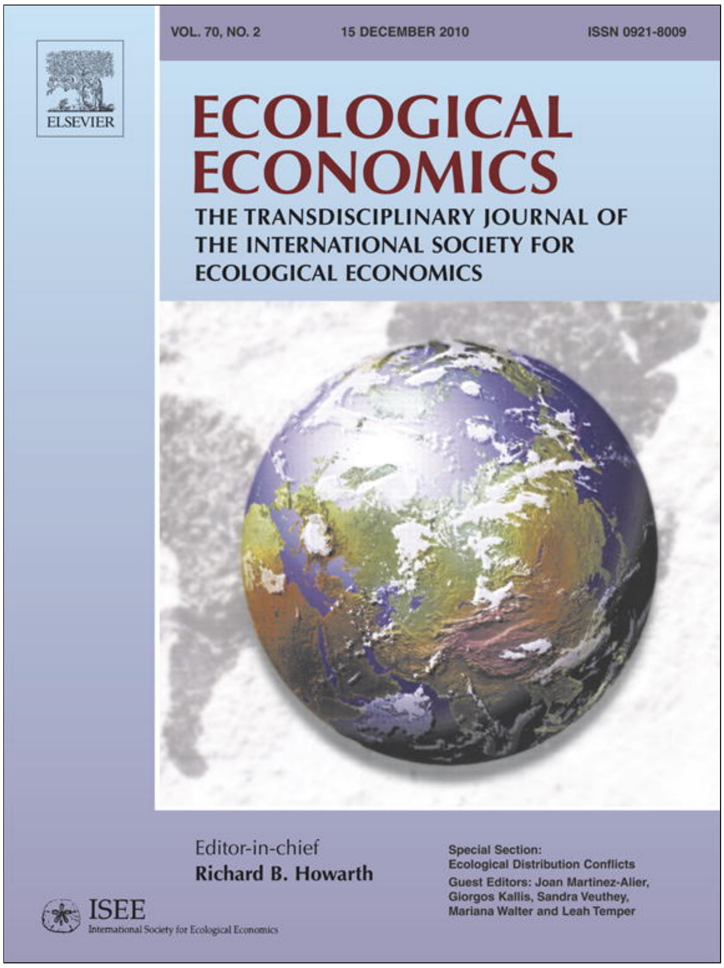
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Biophysical structure of the Ecuadorian economy, foreign trade, and policy implications

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ABSTRACT

At the core of this paper lays the notion that a systematic analysis of material flow accounts enables us to discuss the sustainability of an economic model. Ecuador is going through a socio-ecological transition from an agrarian towards an industrial regime, based on the use of nonrenewable sources of materials and energy. Direct material flow indicators are used in this article to analyze the ecological dimension of the economy of Ecuador during 1970–2007. This approach enables the concept of societal metabolism to become operative. The paper compares societal metabolic profiles showing that per capita use of materials is still at about one-fifth of the average in the high income countries of the world. Physical flows of trade indicate that there is an ecologically unequal exchange. Whereas a positive trade balance is desirable from an economic policy, its counterpart in physical units has been a persistent net outflow of material resources, the extraction of which causes environmental impacts and social conflicts.

1. Introduction

This paper discusses issues of resource use in Ecuador by using the approach of societal metabolism (Ayres and Simonis, 1994; Fischer-Kowalski, 1998; Fischer-Kowalski and Haberl, 1993, 1997). This framework allows an analysis of the structure and trends in internal and foreign physical flows. The metabolic profile of Ecuador and its physical flows of exports and imports are placed in a global context to explore trends in ecologically unequal exchange. This is particularly relevant because the country's participation in world trade has implied environmental depletion and deterioration. Second, this article takes a broad perspective on the internal interactions that exist between the economy and the natural environment, through material flow accounting (MFA) over a forty year period. MFA describes in a simplified way the relationship that exists between the economy and nature. Physical flows illustrate some of the pressures that the use of materials puts on the natural environment. A third contribution of this article is the analysis of resource extraction conflicts in light of MFA, linking the study of social metabolism to the study of political ecology.

A current debate on economic policy confronts those in Ecuador who push for export-led growth (where mining exports would be added to – and substitute in the future for – declining oil exports) and those who take an ecological economics line (Acosta, 2009), emphasizing the environmental and social costs of primary exports. The present analysis is intended to contribute to this policy debate which is relevant also for other countries. Should Ecuador continue to be a primary exporter or should a totally different post-petroleum economy be developed? A related concern is the existence of a hypothetical 'resource curse' in the country, as abundant natural resources are progressively depleted or deteriorated because of the requirements of unsustainable economic growth.

This article presents direct material flows and indicators that have been calculated for the Ecuadorian economy (1970–2007). Flows assessed are domestic extraction (DE), physical imports (M), and physical exports (X). Material flow indicators are: direct material input (DMI), domestic material consumption (DMC), and physical trade balance (PTB). Although these accounts do not include unused extraction, nor do they include indirect flows of foreign trade, they describe the main biophysical dimensions of the economy.

This article is divided into four sections. The first section is the introduction; the second one explains the methodology used to calculate the material flow indicators of the Ecuadorian economy and identifies the data sources. The next section gives results for foreign trade and the domestic economy, including a brief analysis of the socio-ecological transition in the economy, a comparison with the global scale, and an analysis of resource extraction conflicts. The fourth section introduces some options for the future of the economy of Ecuador, taking into account the current debate on economic policy, and the growing visibility of environmental conflicts, and draws final conclusions.

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2. Methods and Data Sources

The empirical work presented in this article is based on the standardized methods and directions formulated in the official methodological guides available. In particular, the methodological guide of the European Office of Statistics (Eurostat) published in 2001, the empirical report on the European Union (Eurostat, 2002), and the Compilation guide of Eurostat (2007). More recently, OECD (2008) has become another source. At least at the time of writing, the ECLAC (UN Economic Commission for Latin America and the Caribbean) is not yet publishing and analyzing MFA for the countries that belong to this organization despite the fact that work on MFA is relevant to debates on international trade and economic policy. Leadership in this work has been taken on by university researchers only: Giljum (2004), Gonzalez and Schandl (2008), Pérez-Rincón (2006), Russi et al. (2008), Vallejo (2006a,b), Vallejo et al. (in press).

Although much progress has been made in MFA concepts and methodologies, building a complete balance of materials for an entire economy remains a complex undertaking. Many of the difficulties arise because economic statistics do not provide all information necessary for every MFA category. Although the mass balance principle[1] enables numerous double-checks for data quality, coherence and consistency; some flows, particularly the output flows and the balancing items are difficult to obtain or are irregularly available.

This study presents a compilation of direct material flows gathered at a macroeconomic scale in Ecuador. A series from 1970 to 2007 has been calculated. Figures presented in Russi et al. (2008) have been improved in this article, through updated methods and expanded data — in particular regarding metal ores and building materials.[2] Material flows accounted are: DE, X, M. Derived indicators computed are: DMI, DMC, and PTB. In Table 1 these flows, indicators, main material categories are classified and detailed data sources are given.

Material categories analyzed are: biomass, fossil fuels, metal ores, industrial minerals, and building materials. Biomass includes all renewable resources obtained through agriculture, cattle grazing and fodder, forestry, and fishing — although biomass may be extracted at unsustainable rates. Fossil fuels and minerals, on the other hand, account for nonrenewable resources. Increasing patterns of DE point to natural resource exhaustion.

The time series of these material categories are based on statistical data compiled by international organizations as detailed in Table 1. This information was originally collected by national statistical offices – as the Central Bank of Ecuador (BCE in Spanish) in the case of foreign trade figures – and afterwards officially reported to international offices. Even if certain weaknesses of the data persist because some flows are underestimated or not reported in official statistics – illegal forestry, and building materials – a standardized methodology was applied and estimations are in conformity with Eurostat methods. Therefore, international comparisons of the material flows and indicators assessed are consistent for the whole period analyzed.

In the case of wood harvested, although illegal forest clearance and the domestic consumption of fuel wood directly collected by rural households introduce some uncertainty in statistics, FAO is a reliable data source. The WB (2006) calculates that 70% of the total production comprises illegal extraction. In spite of the control and monitoring systems, the total quantity of wood extracted and commercialized in Ecuador remains unknown. According to assessments from ITTO (2008), the legal production of wood in 2007 was about 1.9 million m^3. As result, it can be estimated that production including illegal activities was around 5.3 Mt (million tons) in that year. In contrast, FAO reports 6.2 Mt extracted in the same year, taking into account for the DE of fuel wood, wood roughly prepared, and other industrial roundwood.

Minerals accounts reported by the USBM (2009) comprise metallic and nonmetallic minerals. The former are accounted for as mine outputs, which is the weight of ores as they emerge from the mine before treatment — instead of the net metal content, which excludes the output from auxiliary processing at or near the

Table 1
Definitions and data sources.
Sources: Eurostat (2001, 2002, 2007) and author's elaboration.

Category of flow, indicator or material	Description	Data sources
Material flows		
Domestic extraction	The purposeful extraction or movement of natural materials by humans or human-controlled technology (i.e., those involving labor).	See material categories.
Physical imports and exports	Import and export data classified by the level of processing (ISIC Rev. 2) and the main material component.	UNSD (2009) compared to BCE (2009).
Material flow indicators		
Direct Material Input (DMI)	Domestic and foreign material inputs for economic activities. Used domestic extraction + physical imports.	
Domestic Material Consumption (DMC)	The fraction of all materials that remains in the economic system until released to the environment. Used domestic extraction + physical imports – physical exports.	
Physical Trade Balance (PTB)	The net outflow (inflow) of materials from (towards) the domestic environment towards (from) foreign economies. Physical imports – physical exports	
Material categories		
Biomass	Biological materials moved by humans and livestock per year.	
Primary crops	Cereals, roots and tubers, dry legumes, oleaginous plants, vegetables and melons, fruits, fibers, and other primary crops (stimulants, sugar cane, spices, and flowers).	FAO (2009).
Grazed biomass	Demand for forage of livestock units.	FAO (2009).
Forage	Crop residues of sugar cane and cereals used as forage.	(FAO, 2009; OLADE, 2007).
Forestry	Wood harvested from forests, plantations, or agricultural lands: fuel wood, roundwood and wood roughly prepared.	FAO (2009).
Fishing	Captures of fish, crustaceans, mollusks, and aquatic invertebrates.	FAO (2009).
Minerals	Metal ores and industrial minerals production measured in its gross metal content.	USBM (2009).
Building materials	Sand and gravel used for concrete and asphalt production, and other building materials employed.	(IRF, 2009; UNSD, 2009; USBM, 2009).
Fossil fuels	Production of fossil fuels.	OLADE (2007) compared to OPEC (2007).

[1] This principle derived from the Lavoisier's law of mass conservation (Lavoisier, 1965 [1789]) establishes that for every process of process chain, the mass inputs must equal the mass outputs, including wastes (Ayres and Ayres, 2002).

[2] Information presented in Vallejo (2006a,b), and later used for comparative purposes in Russi et al. (2008) reported the periods 1980–2003 and 1980–2000, respectively.

mines.[3] Nonmetallic minerals include industrial and building materials. Building materials, however, could be underestimated in the USBM's reports. Therefore, these figures are calculated by following a recently proposed estimation (Krausmann et al., 2009), which is based on cement and bitumen production figures.[4]

3. The Material Flows of the Ecuadorian Economy

This section combines MFA and the traditional monetary perspective to address the concerns that exist about the development model. Physical indicators do not modify traditional economic accounts for GDP, they complement the System of National Accounts through 'satellite' accounts for environmental pressures due to economic activities. Fig. 1 shows an upward trend of the Ecuadorian GDP over the period analyzed, whereas material flow indicators show also increasing patterns of extraction, consumption, and export of natural resources accompanying the economic growth. As Falconi and Larrea (2004: 136) explain, Ecuador´s recent economic history is characterized by "the loss of native vegetation through changes in the use of land (erosion and deforestation), high population growth rates, a constant deterioration of the biophysical capital (especially of tropical forests) that has destroyed biodiversity, oil extraction (approximately 3.1 billion barrels between 1970 and 2002) and its adverse social and environmental impacts (especially due to oil spills)." In this context, MFA are relevant analytical tools to understand the environmental dimension not considered in traditional statistics.

3.1. The Physical Trade Balance (PTB)

The physical trade balance (*PTB*) is calculated by subtracting export flows (*X*) from import flows (*M*): opposite to the widely known monetary trade balance ($X - M$). Following the logic that monetary and physical imports and exports flow in opposite directions: imports (exports) mean money leaves (come into) the country whereas materials move into (leaves) the country. Positive or negative, a disequilibrium in the PTB reflects that materials are being distributed unequally among nations. More specifically, a negative PTB indicates that the country is a net exporter, which means that there is a net outflow of domestic materials. More resources are exiting than entering the domestic economy. These resources are obtained through extracting processes that deteriorate the environment; they put pressure on renewable and non renewable domestic resources to the benefit of importers (Giljum and Eisenmenger, 2004). There is in principle an ecologically unequal exchange (Cabeza and Martinez-Alier, 1997).

Physical and monetary trade indicators exhibit divergent trends. In physical terms, Ecuador's trade balance has been continuously negative as showed in Figs. 2 and 3. The difference between imports and exports increased from 73.8 thousand tons to 16.6 Mt between 1970 and 2007. In monetary terms the commercial trade balance ($X - M$) went from a deficit of US$82 million to a surplus of US$455 million in the same period. Thus, physical accounts show that a favorable monetary trade balance has been promoted at the expense of exhaustible natural capital.

[3] Data on gold, silver, copper, lead, and zinc are reported by the USBM in their 'recoverable content' after treatment. Instead of that net metal content, the international MFA convention requires to account for the run of mine production. Therefore, conversion factors to calculate the mass of the crude ore are based on concentrates or metal contents applied by Eurostat (2007), Gonzalez and Schandl (2008), and Russi et al. (2008).

[4] A ratio of cement to concrete of 1:6.5 is assumed to compute the amount of sand and gravel used for concrete. Likewise, a ratio of bitumen to asphalt of 1:20 accounts for the volume of materials employed to produce asphalt. The rest of building materials required to different purposes are counted from the USBM.

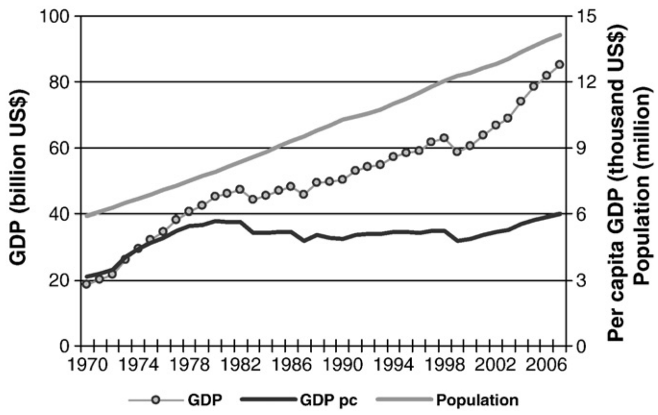

Fig. 1. Economic and population trends. *Note:* GDP figures in PPP dollars at 2005 constant prices.
Sources: Penn World Table 6.3 — Heston et al. (2009) and CELADE (2009).

Economic policy seeks to direct the economy towards the attainment of an internal and external equilibrium – towards full employment, price stability, balance of payments in equilibrium – ignoring, however, the socio-metabolic aspects related to economic activities that negatively affect the environment.

The balance of payments measures the monetary flows generated by international trade (the commercial balance), migrants' remittances, foreign direct investment, and external funding (the capital balance). In particular, it provides an approximation of the amount of currency available to carry out economic transactions, something very relevant in a dollarized economy like Ecuador. In this sense it is desirable to reach a positive commercial balance. However, this economic target can encourage environmental depletion and deterioration through natural resources exports.

In terms of inflows of foreign currency, bananas represented 44% of total exports in 1970 whereas oil represented 58% in 2007. Bananas measured in tons were 80% of exports in 1970 and crude oil 63% in 2007. When analyzing non-petroleum trade, the country's trade surplus disappears. The most important exception is 1999, a year in which a severe economic crisis caused imports to contract by 38%. These aspects are presented in Fig. 4. Dependence on natural resources exports has been a structural characteristic of this economy. A historical analysis on specialization patterns and dependence on exportable ecological flows is developed in Acosta (2009).

The beginning of the 'oil age' implied a sudden increase of the volume of physical exports from 1.6 Mt in 1970 to 8.5 Mt in 1979. Paradoxically, increasing exploitation and export of natural resources

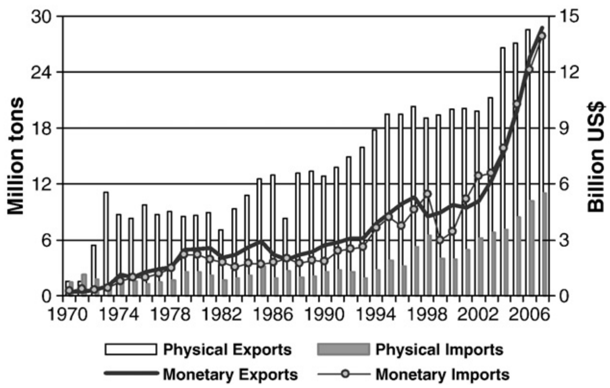

Fig. 2. Physical and monetary trade flows.
Source: Author's estimations.

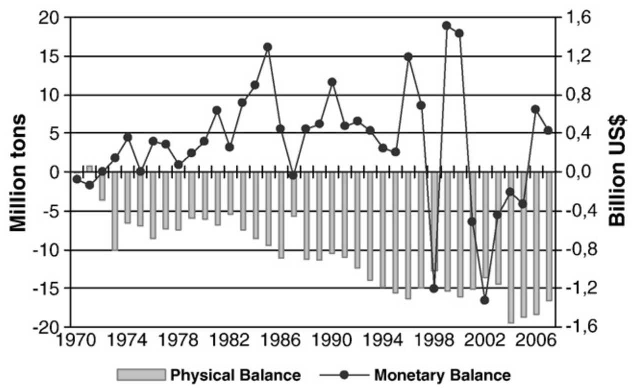

Fig. 3. Trade balances.
Source: Author's estimations.

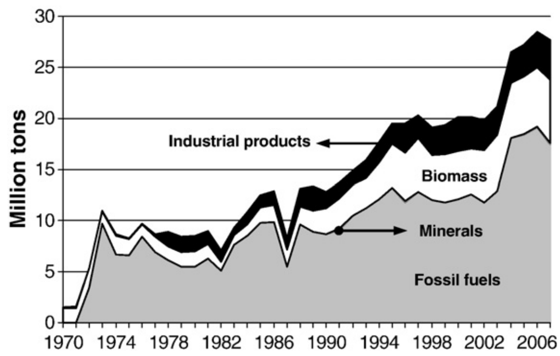

Fig. 5. Material exports.
Source: Author's estimations.

are related to periods of economic crisis as well as periods of economic expansion. For instance, during the oil boom of the 1970s and the more recent oil boom until 2008, increases in export revenues have been accompanied by increases in the amount of materials exported. Rates of growth registered in the 1970s were 33% and 21% in monetary and physical units, respectively. Likewise, the rates registered in the 2000s are 17% and 4.7%. During the so called 'lost decade' of the 1980s, the growth of physical exports did not decrease. It was similar to that registered during the 1990s and 2000s, about 5%. This implies that as reaction to the crisis reflected in GDP (a rate of minus 2% in the 1980s) and monetary exports (decreased at minus 1%) environmental pressures were fostered through a more intensive DE of natural resources and the expansion of physical exports, as showed in Fig. 5. The economy's adjustment to the crisis was biophysical since the amount of natural resources exported increased to compensate for the stagnation of monetary flows.

Exports increased physically eighteen times between 1970 and 2007, whereas imports increased seven times. Hence the persistently negative PTB. Notice however that import flows expanded especially during the period when Ecuador has been dollarized, from 1.5 Mt in 1970 to 3.9 Mt in 2000, and then to 11 Mt in 2007.

This assessment, however, does not include the so called 'raw material equivalents' (RME) (Eurostat, 2001; Weisz et al., 2004). These are indirect flows associated to imports and exports, the upstream material requirements of used extraction (intermediate inputs). Certain bias could remain in the analysis when considering only direct flows. Large quantities of materials indirectly related to the DE have to be discounted from DMC because although they remain in the domestic environment as wastes, they are in fact the result of international trade requirements.

Muñoz et al. (2009) determine that the Ecuadorian deficit in the PTB diminished when the raw material trade balance was estimated, from 15 to 9 Mt. Each ton exported by Ecuador needed about 0.4 tons of indirect flows that remained in the country in the form of wastes and emissions, whereas each ton imported required the movement of 2 tons of indirect flows in the country of origin. According to Muñoz et al. (2009), this is explained because indirect material flows of imports are driven by manufactured goods, which require more material inputs along the production chain than exports dominated by oil. In these figures, however, a crucial component of the indirect flows is not accounted for, unused extraction. RME only refers to 'used materials', that is, those material flows that enter economic processes. During extraction, however, some materials are moved but with no intention of using them as inputs for production or consumption (Eurostat, 2001). In the case of Ecuador, these materials comprise deforested or cleared biomass without an economic use. They would also comprise the 'production water' coming up with the oil (and dumped into ponds or re-injected), and the gas flared in situ.

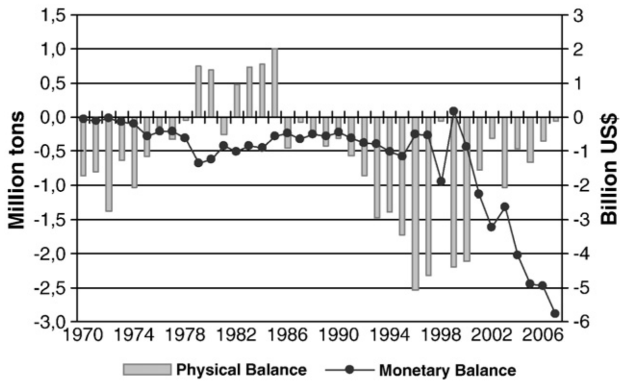

Fig. 4. Trade balances — Non-petroleum commodities.
Source: Author's estimations.

3.2. The Terms of Trade

The Latin American 'structuralist school' introduced six decades ago a theory on economically unequal exchange between central and peripheral economies. Prebisch's approach rested on the notion that the prevailing international division of labor determines that peripheral countries are specialized in exporting primary goods whereas central countries export industrial goods. The terms of trade for peripheral countries tend to deteriorate (Prebisch, 1950). These influencing ideas have been currently recovered in ecological economics in the debate on ecologically unequal exchange, a concept suggesting that unbalanced trade flows between North and South determine environmental liabilities and social costs not included in international prices.

Asymmetries in the value of imports and exports encourage intensification of natural resource exploitation in order to acquire the same amounts of imported goods (Giljum and Eisenmenger, 2004; Hornborg, 1998; Muradian and Martinez-Alier, 2001). The extractive economies advance towards an irreversible exhaustion of natural resources whereas industrialized economies show internal improvements towards dematerialization but they employ more materials from beyond their borders (Giljum, 2006). The more of the original available energy (or productive potential) in the exported raw materials has been dissipated in producing the final products or services, the higher the prices of these final products or services will be. Therefore, market prices are the means by which world system

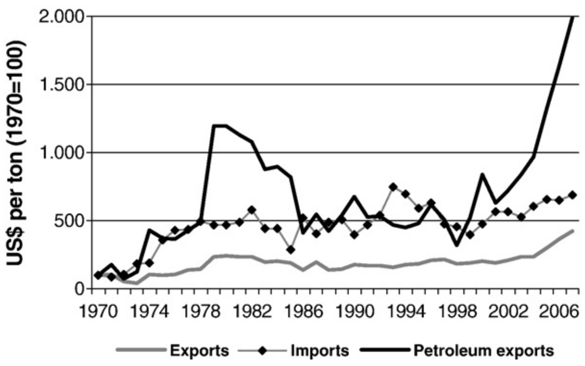

Fig. 6. Unit values of trade.
Source: Author's estimations.

centres extract available energy (also known as exergy) from the peripheries (Hornborg, 1998; Naredo and Valero, 1999).

In this line of thought, Bunker (1985, 2007) argued that 'natural values' embodied in primary products exported are underpaid or not recognized at all in foreign trade relations. Bunker posits a structural asymmetry between 'extractive economies' in the periphery and 'productive economies' in the core. A pattern of specialization in exporting goods intensive in natural resources and low qualified labor – as the pattern characterizing many Latin American countries – contributes to low economic development. Natural resource providers are frequently relocated, as nonrenewable and even renewable resources are eventually exhausted. Regions depending on exporting natural resources are therefore likely to suffer from severe fluctuations in income, unable to sustain a path of development and to establish strong social and political structures.

Unit values (US$ per kilogram) of imported and exported materials (base year 1970) are presented in Fig. 6. During the period of analysis there has been a wide gap between the value of imports and exports in nominal terms; the price of each ton of material imported is higher than the corresponding price of exports, by a factor of 1.5 in 1970 and 2.4 in 2007. Import unit values increased at a more rapid pace than export unit values, rates of growth from 1970 to 2007 are 5% and 4%, respectively. Therefore, the relative decrease of export prices with respect to import prices means that the terms of trade have worsened by −1.3% annually.

A cyclical behavior of terms of trade shows that periods of recovery can also take place with different implications for productive and extractive economies. In Ecuador, these recoveries are associated to petroleum international price bonanzas registered in the 1970s until the early 1980s, and more recently during the 2000s until 2008. However, these notable increments of petroleum export prices were not sufficient to break the structural disparity between industrial import prices and commodity export prices. In terms of environmental pressures and permanent loss of resources, the worst part of the exchange is suffered by the extractive economies. On the other hand, for the importing countries higher prices of essential bulk commodities – like oil – would slow down their economies, and perhaps cause world economic crises.

3.3. Socio-Ecological Transitions in the Ecuadorian Economy

Notions of 'metabolic profiles' (Schandl and Schulz, 2000) and 'socio-ecological transitions' (Fischer-Kowalski and Haberl, 2007; Krausmann et al., 2007) are employed in this section to analyze the transformation of the Ecuadorian economy in the light of material use patterns. DE, DMI, and DMC show the advances of this economy in the transition from an agrarian regime into an industrial regime.

Metabolic profiles are defined by the structure and level of material use. On the other hand, socio-ecological transitions imply a continuous process of social change where the structure of a society and the related environmental relations this society has established transform themselves (Schandl et al., 2009). Some stylized facts are distinguishable between different socio-ecological regimes: metabolic profiles, demographic features, spatial patterns of land use, socioeconomic organization, infrastructure networks, and technologies. These authors distinguish some parameters of metabolic profiles in agrarian and industrial societies, which are compared with the Ecuadorian economy's parameters in Table 2.

Most of the features depicted by the Ecuadorian metabolic profile enable us to identify this economy in a slow transition from an agricultural into an industrial pathway. This is also the case of other South American countries, as analyzed by Eisenmenger et al. (2007) for Brazil and Venezuela, or Vallejo et al. (in press) for Colombia.

Ecuador 'spent' the income from oil since the 1970s to the early 2000s in population growth more than in establishing the bases for an industrial economy (Falconí, 2002; Falconí and Ramos-Martin, 2003). The rate of population growth is now rapidly declining. In terms of material flows, one first element to consider is that currently, as 40 years before, biomass remains as the main resource base of this economy (79% of the per capita DMC in 1970 and 38% in 2007). However, it has decreased through the years. In contrast, the building sector has gained participation and currently reaches almost the same fraction than biomass (36%). The major share of materials that entered the economy – the direct material inputs – did so through DE in agriculture (67% of per capita DMI). Material imports were smaller fractions (5% in 1970 and 9% in 2007). Today, the DE of construction materials is also a significant component (28% of the per capita DMI in 2007).

The most relevant factors to explain the growth of building materials consumption in the country are the large scale urbanization process – only 34% of the population is now located in rural districts – and the recent expansion of housing financed by migrant's remittances.

Fossil fuels participation in DMC has increased from 4% to 12% in a period of almost forty years. These materials are mostly exploited to satisfy the foreign demand, but Ecuador's energy system has come also to use relatively large amounts of fossil fuels.

Table 2
Metabolic profile of Ecuador compared to agrarian and industrial socio-ecological regimes.
Sources: (a) Krausmann et al. (2008), (b) author's estimation, (c) WB (2010) and (d) FAO (2010).

Indicators	Units	Agrarian regime	Industrial regime	Ecuador 1970	Ecuador 2000	Ecuador 2007	Sources
Per capita energy use	GJ/cap	40–70	150–400	na	73.8	na	(a)
Per capita material use	t/cap	3–6	15–25	4.9	6.2	7.4	(b)
Population density	cap/km^2	<50	<400	21.1	43.4	47	(c)
Agricultural population	%	>80	<10	41*	26	21	(d)
Energy use per area	GJ/ha	<30	<600	na	32.9	na	(a), (c)
Material use per area	t/ha	<2	<50	1	2.7	3.6	(b), (c)
Share of biomass in energy use	%	>95	10–30	na	60	na	(a)

* Information corresponds to 1980.

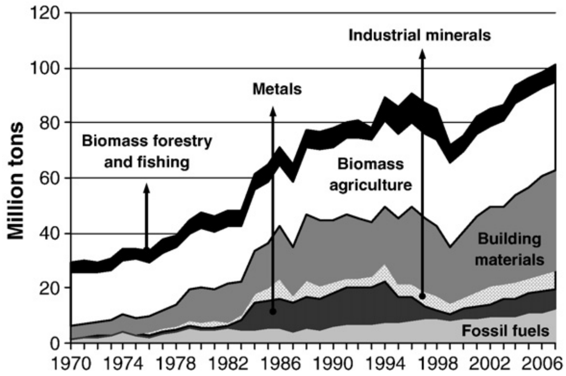

Fig. 7. Domestic material consumption.
Source: Author's estimations.

Increasing trends in the aggregate material flow indicators were temporarily halted in 1987 and 1999. A major earthquake damaged the pipeline and paralyzed oil production in 1987, and at the end of the 1990s a financial crisis slowed down the economy. This resulted in the dollarization of the economy. The trends in the physical level and structure of the economy through the years can be analyzed in Fig. 7, where the evolution of DMC is presented.

The population grew from 6 to 13.6 million inhabitants since 1970. The active agricultural population diminished from 41% to 21% between 1980 and 2007 — according to FAO statistics available. The labor employed in agriculture increased slightly. In part this goes together with the opening of the agricultural frontier in some areas. Yields increased little. In the aggregate, from 7.4 to 8.3 tons per hectare between 1970 and 2007. Ecuador's agriculture has some parts which are already industrialized (bananas, oil palm), but the country as a whole has until recently experienced a small increase in absolute terms in the active agricultural population, a trend that does not fit at all with an industrialization process.

A second element to analyze is related to energy sources. Based on Krausmann et al. (2008) estimations of the Ecuadorian energy flows in the year 2000, 61% of the energy supply (accounted by $DE+M$ in energy units) comes from oil, agricultural biomass represents 32% of the total supply, and total biomass 37%. These percentages are far from the 80 or 90% of biomass of agrarian societies (Table 2).

A new industrial regime is appearing. It is different from the historical industrialization process of the 'mature' developed economies because resources are already scarce. The industrial energy system is based on the exploitation of large stocks of fossil fuels — crude oil in the case of Ecuador because coal is not exploited. Therefore the reliance on an exhaustible resource does not allow for long terms sustainability of the economy (De Vries and Goudsblom, 2002; Schandl et al., 2009).

Features of the industrial pathway would be the substitution of human labor by mechanized processes, the expansion of the services sector, and the outsourcing of labor as well as resource and emission intensive activities to the periphery (Haberl et al., 2006; Weisz et al., 2006). Whereas some of these characteristics are identified in Ecuador (the services sector has expanded through the years, reaching 57% of GDP in 2007), however, as explained before, a large part of the active population is still in agriculture, and Ecuador certainly does not outsource labor nor 'dirty' processes to the world periphery. Ecuador is part of the world periphery, exporting migrants (until 2008) and exporting oil and other primary products.

The use of materials measured in terms of per capita DMC increased only by a factor of 1.5 over nearly forty years. Population expanded by a factor of 2.3 — although the rate of population growth is now declining. Per capita agriculture biomass consumption – mainly associated to the population's nutritional requirements and one of the major components of DMC – shows a decreasing trend although brief recoveries were registered in 1986–94, and 2002–04.

After exploring the metabolic profile of the country and comparing it with the industrial regime, it can be concluded that significant growth in the use of nonrenewable materials and energy sources can be expected in the coming years if the economy is to grow, even when taking into account the decline in population growth. Given the exhaustibility of oil reserves, a change of economic structure is required.

Finally, we ask whether there are signs of relative dematerialization in Ecuador's socio-ecological transition. Dematerialization refers to the process of fulfilling society's functions with a decreasing use of material resources over time (Cleveland and Ruth, 1998; Van der Voet et al., 2008). It is often argued that a characteristic of modern mature economies is the lowering of material inputs if not in absolute terms at least per unit of GDP (Adriaanse et al., 1997; Matthews et al., 2000).

In the economy of Ecuador in absolute terms the use of materials is expanding – especially as regards nonrenewable inputs – and it will increase in the future if there is economic growth following the path of the socio-ecological transition towards industrialization. In terms of material efficiency, however, the Ecuadorian economy shows some progress. The 'resource productivity' – measured by the economic output generated by each unit of materials used – has increased slightly. This implies that the 'material intensity' (measured as the inverse relationship of DMC to GDP) has diminished as shown in Fig. 8. Only 76% of the amount of materials consumed in the 1970s was required to produce one dollar of GDP in 2007. It implies a small annual improvement of 0.8% along almost 40 years. However, there are different trends in different periods.

A relative dematerialization indicates that physical pressures exerted on the environment grow less than the economy, which is a good sign from the point of view of 'weak sustainability'. Nevertheless, the territory and the resources of the country are limited, therefore relative dematerialization is not equivalent to sustainability in the long run.

Is the debate on dematerialization relevant for the so-called 'resource curse'? The 'resource curse' (Auty, 1993; Gavin and Hausmann, 1998; Sachs and Warner, 1995, 2001) is defined as a situation of economic stagnation and social conflicts determined by the abundance of natural resources. The Ecuadorian economy has not stagnated, it has maintained an increasing population with some gains in income per capita and material efficiency, although certainly the natural resources are depleted and socio-ecological conflicts emerge with extractive pressures. There is no economic-environmental policy addressing long term sustainability. Although the current government has some plans to replace oil and promote renewable sources of electric generation – mainly hydroelectric – which are not free of environmental and social implications, there are contradictory signals for attaining a sustainable development. At one extreme is the Yasuni-ITT Initiative (Finer et al., 2009; Larrea and Warnars, 2009), which is meant to leave about

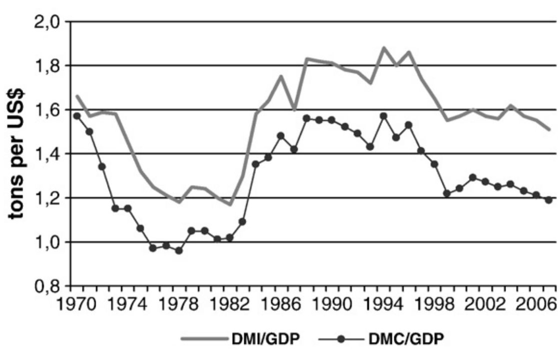

Fig. 8. Material intensity of Ecuador. *Note:* GDP figures in PPP dollars at 2005 constant prices.
Source: Author's estimation.

850 million barrels of crude oil in the soil in an area of the Amazon of great biodiversity, inhabited by voluntarily isolated indigenous peoples. Ecuador would lose revenue. According to the government, Ecuador is ready to make this sacrifice provided there is an international compensation which covers at least half the foregone revenue. At the other extreme there are plans to take out all the oil reserves (Ecuador has passed peak oil already) as far as the market demands, and also start large scale exploitation of mineral resources. Socially, the Yasuni ITT proposal has become symbolic of the crossroad in policy. Also the local resistance against copper mining in Intag (in the north), and Cordillera del Condor (south-east), and the successful stop to oil exploration by the indigenous population in Sarayacu, signal possible alternatives. The Yasuni-ITT would be the starting point of a new model breaking dependence on petroleum, and definitely it would mean a clear dematerialization policy preventing carbon dioxide emissions without precedent in the world.

Whereas industrialized countries are dematerializing in relative terms, they import increasing amounts of metal ores, fossil fuels, and other products from the South (Giljum and Eisenmenger, 2004), at least until the crisis in 2008. New industrialized regions in China and elsewhere, become large net importers of raw materials. Other countries, conversely, in Latin America and also in Africa, necessarily intensify their specialization in primary goods exports although prices do not take into account the negative impacts on their environments.

3.4. Where is Ecuador on the Global Scale of Material Use?

The position of Ecuador in the socio-metabolic profile on a global scale is analyzed here. As in Krausmann et al. (2008), important differences are identified between developing and developed economies. The relevant finding is that among low-income economies there are also broad margins in the material use. The analysis provided in this section is based on per capita material use indicators of Krausmann et al. (2008) for 175 countries in the year 2000. This information is contrasted with material flows assessed for Ecuador in this article.

The Ecuadorian per capita DMC is behind the average for poor countries with 5.6 tons and only one-fifth of the amount consumed in the group with the highest incomes (28.3 tons). Differences in the DE are similar. A factor of four separates Ecuador from the average of the last quintile. Negative PTB characterize the countries until the second quintile, and a strong negative PTB is registered in the fourth quintile because of the records of Canada and Australia. These are high income economies exporting considerable amounts of natural resources. If they are not considered, the fourth quintile has already a positive PTB. The Ecuadorian PTB is negative because the country exports five times more tons than it imports. These comparisons are summarized in Figs. 9 and 10.

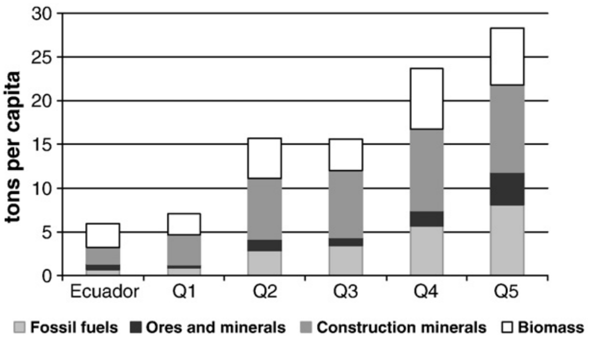

Fig. 9. Comparison of metabolic profiles in terms of DMC.
Sources: Krausmann et al. (2008) and author's estimation.

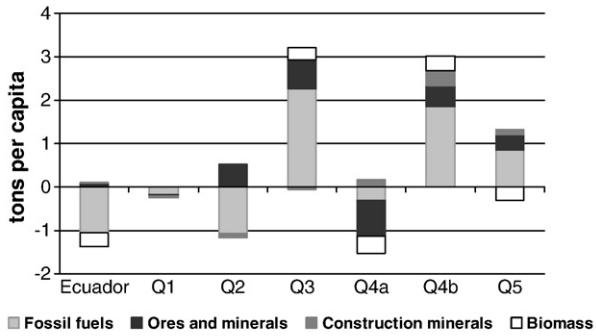

Fig. 10. Comparisons of metabolic profiles in terms of PTB. *Notes:* Qa: fourth quintile including data of Canada and Australia. Qb: fourth quintile excluding data of Canada and Australia.
Sources: Krausmann et al. (2008) and author's estimations.

3.5. Resources Extraction Conflicts

Extractive activities are the source of a variety of ecological distribution conflicts. Pressures exerted on the environmental services and resources upon which poor and indigenous populations depend, give rise to complaints. Pollution and the demand for soil, water, clean air, and other natural resources at the commodity frontiers, are the source of protests and resistance from populations affected.

A systematic analysis of material and energy flows is needed not only to understand the relationships between the economy and the environment, but also to forecast the environmental pressure of economic activities on natural resources and services, to recommend environmental policy alternatives, and also to analyze the ecological distribution conflicts studied by Political Ecology (Berkes, 1989; Blaikie and Brookfield, 1987; Greenberg and Park, 1994; Martinez-Alier, 2002; Martinez-Alier and O'Connor, 1996; Ostrom, 1990; Robbins, 2004; Schnaiberg et al., 1986). A novelty of the present article is the attempt to trace links between Ecuador's metabolic profile – domestic and external – and resource extraction or waste disposal conflicts. This is one of the first attempts to connect the study of societal metabolism to the study of political ecology, opening up a new line of research. Tables 3 and 4 summarize the conflicts discussed below.

Some conflicts arise from the extraction of bulk commodities such as oil, some minerals or timber. Other conflicts are related to 'preciosities', materials of high economic value per unit of weight (Hornborg et al., 2007), such as shrimp or flowers, whose role in the importing countries metabolism is negligible but the production of which damages the environment of Ecuador.

The most famous conflict on oil extraction in Ecuador (and perhaps in the world) is between Chevron-Texaco, and indigenous and settler populations in northern Amazonia. It is a conflict born of soil and water pollution in a unique and irreplaceable ecosystem as a result of crude oil exploitation. A court case claiming damages for billions dollars in favor of local communities has been going on since 1993. After 28 years of operations in what was a pristine rainforest environment, Texaco left environmental and social liabilities for about 30 thousand people depending on the water for drinking, cooking, bathing and fishing. Besides health impacts such as cancer and birth defects, 18 billion gallons of wastewater were directly dumped into surface streams and rivers; 916 open-air, unlined toxic waste pits were built in the forest floor; contaminants were released through gas flaring, and oil was spread on roads (Amazon Watch and FDA, 2010).

Open-cast mining is causing recent conflicts in the country. Mirador is the biggest project registered in Ecuador with the multinational company Corriente Resources (ECSA). It affects Shuar and Saraguro indigenous populations, settlers, and small scale miners. Claims emerge also from conservationists because this southern Amazon territory has large biodiversity wealth (OCMAL, 2009).

Table 3
Resource extraction conflicts regarding bulk commodities in Ecuador.
Sources: Acción Ecológica (2007), CME (2009), Espinel (2001), Guerra (2003), Hernández et al. (2007), Human Rights Watch (2002), Sandoval (2001), Vásquez (2006), Olmos and Torres (2009).

Commodity in conflict	Period and location	Main actors	Social and natural resources affected
Oil	1911–1960 CoA, Peninsula of Santa Elena	MC (Anglo-British Petroleum), State, LC	Water, soil, air, biodiversity, forest, human health, traditional knowledge.
	1970–2001 Am, Aguarico canton-Orellana Prov.	MC (Texaco), NC (CEPE and Petroecuador), LC	
	2003–2007 CoA and the Am	MC (OCP Consortium: Encana, Perenco, Occidental, Kerr McGee, Alberta, Agip, Repsol YPF, Perez Compac, Techint, Petrobras), NC (Petroecuador), State, LC	
Copper	1941–1950 HlA, Macuchi, Cotopaxi Prov.	MC (Cotopaxi Exploration Company-SADCO), State, LC	Soil, water, biodiversity, agriculture
	1975–1981 HlA, Toachi river, Pichincha Prov.	NC (Compañía Minera Toachi), State, LC	
	1995–2008 HlA, Intag, Imbabura Prov.	MC (Bishimetals 1995–1997, Ascendant Copper Corp. 2004–2008), State, LC	
	Am, Cordillera del Condor, Morona Santiago and Zamora Chinchipe Provs. Mirador Project	MC (ECSA: 11.3 million tonnes to exploit), small scale producers, State, LC	
	Am, Cordillera del Condor, Morona Santiago Prov. Panantza-San Carlos Project,	MC (ECSA: 6.4 million tonnes to exploit), small scale producers, State, LC	
Banana	CoA, Guayas, El Oro, Los Ríos Prov.	Small and middle producers, MC (United Fruit-Chiquita, Standard Fruit-Dole, Del Monte), NC (Noboa, Wong, Pons, UBESA-Dole)	Water, soil, forests, human health (DBCP), food security.
Sawlogs and veneer logs	Since 1972 CoA, Esmeraldas, North and South of the Amazonia	NC (Endesa, Plywood, Codesa, Botrosa, Arboriente), settlers, LC	Water, soil, biodiversity, forests, labor options for local communities.
Fiberboads, sawnwoods	Since 1978 HlA, Cotopaxi and Pichincha Provs.	NC (Acosa, Novopan, etc.), settlers, LC	
Wood for paper pulp export: eucalyptus	Since 1990s CoA, Muisne, Esmeraldas Prov.	NC (EUCAPACIFIC), MC (Electric Power Development, Sumitomo Corporation, Mitsubishi Papers Mills y Waltz International), settlers, local producers and LC	

Notes:
HlA: Highland areas.
MC: Multinational Companies.
CoA: Coastal areas.
Am: Amazonia.
NC: National Companies.
LC: Local communities.
Prov: Province.

Banana, oil palms, flowers, and other monocrops produced to export demand big amounts of soil, water, and agrochemicals. There are internal conflicts because food security is at risk, with lower quantities available or a diminished quality due to contamination. Banana production requires to clearing the land of forest. Then, every ton of banana exported requires 0.4 tons of natural fertilizers and agrochemicals, 0.1 tons of packing materials (mainly wood and cardboard), and 841 m^3 of water throughout all cultivation stages; without accounting for health impacts and economic losses caused by water pollution (Vallejo, 2006a). New conflicts are arising with oil palm plantations.

The main conflict in shrimp exports is between local populations sustainably using the mangroves, and the shrimp export industry that uproots the mangroves to grow shrimp in ponds (Martinez-Alier, 2002). Another conflict emerged between shrimp and banana producers regarding the use of agrochemicals in banana plantations. Water pollution caused by agrochemicals could produce a shrimp illness identified as ‘Taura syndrome’, because of the town on the Ecuadorian coast where it appeared for the first time. It expanded along the centre and south of the coast. Downstream polluted waters affected shrimp ponds, causing the loss of the shrimp harvest. The most difficult moment of the conflict was in 1994, when banana producers refuse to stop fumigations, arguing the lack of scientific proof for the Taura syndrome.

Finally, regarding forestry, the case of PROFAFOR FACE presents interesting features. FACE is an international company created in 1990 by a consortium of electric generation companies from The Netherlands, whose objective was establishing 150 thousand hectares of forest plantations in developing countries, to compensate for the carbon dioxide emissions from a coal power station in that country. PROFAFOR is the national company in charge of the establishment of pine monocrops on behalf of FACE. Some problems related to this project are soil erosion, alterations of the water cycle and loss of water sources for the Andean region, emission of carbon dioxide due to vegetation clearance for establishing plantations, loss of biodiversity, and small or o even negative benefits to poor peasant communities, who sell the carbon credits in exchange for wood sales at the end of the contract (15 or 30 years). Meanwhile they are responsible for all activities, including sometimes replanting in case of fires. Other conflicts regarding tree plantations have also arisen, as with Japanese firms planting eucalyptus for export in the coast (Gerber et al., 2009; Granda, 2005).

Resource extraction conflicts are caused by the increased social metabolism for domestic consumption and exports. However, building materials cause fewer conflicts (in proportion to tonnage) than oil or mining. This is not to say that no conflicts have arisen, as with pollution from cement factories, like Selva Alegre close to Quito.

4. Conclusions and Policy Options

Ecuador faces a double challenge. Simultaneously maintain the integrity of sensitive territories because of their social or ecological characteristics, and improve standards of living of the population. The

Table 4
Resource extraction conflicts regarding 'preciosities' in Ecuador.
Sources: Acción Ecológica (2007), CME (2009), Espinel (2001), Guerra (2003), Hernández et al. (2007), Human Rights Watch (2002), Sandoval (2001), Vásquez (2006) and Olmos and Torres (2009).

Commodity in conflict	Period and location	Main actors	Social and natural resources affected
Gold, and silver	1904–1950 CoA, Portovelo-Zaruma, El Oro Prov.	MC (South American Development Company-SADCO), State, LC	Water, soil, air, human health.
	1941–1950 HlA, Macuchi, Cotopaxi Prov.	MC (Cotopaxi Exploration Company-SADCO), State, LC	
	1950–1978 CoA, Portovelo-Zaruma, El Oro Prov.	NC (CIMA), State, LC	
	1975–1981 HlA, Toachi river, Pichincha Prov.	NC (Compañía Minera Toachi), State, LC	
	1978–1992 CoA, Portovelo-Zaruma, El Oro Prov.	NC (State's CIMA), State, LC	
	1980s–1990s–2000s Am, Nambija, Zamora Chinchipe Prov. CoA, Portovelo-Zaruma, El Oro Prov. HlA, Ponce Enriquez, Azuay Prov.	Artisanal miners (1980s), miners' associations (1990s), NC (Minpalca in Ponce Enriquez, Andos in Nambija), MC (IamGold in Portovelo-Zaruma), State, LC	
	Fruta del Norte Project, Am, Cordillera del Condor, Zamora Chinchipe Prov.	MC (Kinross-Aurelian: 13.7 and 22.4 million ounces of gold and silver, respectively), State, LC	
	Rio Blanco Project, HlA, Molleturo, Azuay Prov.	MC (International Minerals Company: 650 thousand ounces of gold and 4.2 million ounces of silver), State, LC	
	Quinsacocha Project, HlA, Giron, Azuay Prov.	MC (IamGold: 3 million ounces of gold), State, LC	
Shrimp	Since the 1980s CoA, Muisne, Esmeraldas Prov.	Small and middle producers, LC	Mangroves, water, labor options for local communities
	Since the 1980s CoA, Esmeraldas (North Coast), Guayas, El Oro, Manabí Provs.	NC (Expalsa, Exporklore, Nirsa, El Rosario-Ersa, Enaca, Songa, Omarsa, Promarisco, Empagram, Oceanpac), middle and small producers, MC related to banana production, LC	
Flowers	1960s–1970s HlA, Pichincha Prov.	NC (Jardines del Ecuador, Florexport), LC	Water, soil, human health, food security
	1980s Pichincha, Imbabura, Cotopaxi, Chimborazo, Azuay, Cañar Provs.	NC (Agroflora, Empagri, Florisol, Agricola Pazcor, Florequisa, El Rosedal, Rosas del Ecuador, Arbusta) and LC	

Notes:
HlA: Highland areas.
MC: Multinational Companies.
CoA: Coastal areas.
Am: Amazonia.
NC: National Companies.
LC: Local communities.
Prov: Province.

theory of socio-ecological transitions leads one to think that, despite much slower population growth, the amount of materials and energy used in the economy will increase in the next years provided there is economic growth. There is need for progress in terms of material efficiency to achieve sustainability. This implies a larger generation of economic value added in the production as well as changes in the material and energy bases of the economy towards renewable sources that do not enter into conflict with the livelihoods of peasants and indigenous populations, and that do not destroy the enormous biodiversity of the country.

Diversification of exports is not a sufficient condition. In addition, it is necessary to export less in quantity, and at better prices. Strengthening the participation of the country in OPEC, promoting regional efforts to create 'cartels' for crucial environmental resources, and establishing export quotas, are some policies to be addressed. Another component of this set of policies could also be the establishment of eco-taxes on the depletion of natural resources to compensate also for local and global negative environmental externalities (Daly, 2007).

This paper has explained the societal metabolism of the Ecuadorian economy (focusing on material flows more than energy). The material flows of Ecuador have been analyzed using the Eurostat standard methodology. The period 1970–2007 is covered. Building materials have increased in periods of economic growth but DE is still dominated by biomass. A progressive shift towards building materials shows that this economy has reached a more advanced stage of development, when infrastructure and housing become material priorities.

The physical growth of the economy of Ecuador has been a bit faster than the (rapid) growth of population. The rate of population growth is now declining whereas material use per capita is increasing. Other signs of an industrial socio-ecological transition are appearing. One is the diminishing participation of agricultural labor and rapid urbanization, another is the prevalence of oil in the domestic supply of energy although most of the energy consumption is still comprised of biomass, and a third one is the growth of the service sector.

The aggregate DE increased by a factor close to four, whereas DMC by a factor three. Comparisons are made with other countries. The economy of Ecuador still uses relatively little of materials per person. For the year 2000, the per capita DMC in high-income economies was five times higher than the Ecuadorian level (6: 31 tons per capita).

Oil and banana exports are the main items in a physical trade balance that is heavily negative. Although material flows for domestic use are larger than those traded in the international markets, it would seem that many export goods have more noxious environmental consequences. For instance, petroleum extraction involves forest and biodiversity losses associated with the need for roads, pipelines, and seismic lines. Additionally, processing pollutes water, soil, and air through the burning of gas, oil spills and wastewater dumped into the environment. Similarly, monocrops – as banana, oil palms, pine or eucalyptus – carry an intensive social and material burden. This burden can be analyzed through material flows directly or indirectly linked to exporting activities, by studying the collateral effects that the activity may generate on workers and the surrounding populations. This is relevant for the agrofuels exports planned for the coming years, and which the economic crisis of 2008 has adjourned.

If there is economic growth, a large increase of DE and DMC of materials could be expected in the coming years. However, oil extraction is not sustainable. In this context, MFA is a relevant tool to analyze policy options for the country in the current debate on a post-petroleum economy. If sustainability is seriously considered, the economy cannot be based on exhaustible resources.

Ecuador is an exporter of primary commodities, and there is a strong debate in the country on what a post-petroleum economy would look like. There are proposals for intensive exploitation of mining resources. If this takes place, it would indeed be reflected in the MFA. To look at the economy not only from a monetary point of view but also from a physical point of view, as in ecological economics, helps to broaden the arguments for the economic policy debate, including proposals for 'natural capital' depletion taxes and export quotas.

Government policy under President Rafael Correa since 2007 is contradictory. On the one hand, the Yasuni-ITT proposal (leaving oil under the ground) clearly shows awareness that serious changes in the prevailing extractive model are needed. On the other hand, plans to exploit oil reserves elsewhere (and even perhaps in the Yasuni itself), plus large scale open-cast mining contradict such intentions.

Those who defend the integrity of the Yasuni-ITT territory like to point out that over the period of extraction of about ten years, it would supply only ten days of oil world consumption. Imagine, however, a world without oil for ten long days. The industrial world economy depends on a continuous flow of energy and materials of enormous proportions. Energy cannot be recycled and materials are recycled only in part. Therefore, with present technologies and consumption patterns there is a need for 'fresh' supplies coming from the commodity frontiers. This is the logic of exploitation of oil or copper resources in Ecuador. Hence, the difficulty in establishing new policy options.

This paper contributes to the theory of ecologically unequal exchange. As theorized by Prebisch in the 1950s, there is a structural trend towards decreasing terms of trade, which is verified in the Ecuadorian economy by the increasing gap observed between import and export prices between 1970 and 2007. This article has analyzed Ecuador's negative PTB. More materials are leaving the country than entering. This implies that the country helps the societal metabolism of importing countries by exporting at prices that do not take properly into account either exhaustion of resources or local negative externalities.

Extractive developing countries such as Ecuador and other countries in Latin America and Africa, are specialized providers of material resources, which cover domestic and foreign requirements, whereas imported resources are small inputs of their societal metabolism (4% of per capita DMI). These countries are advancing towards irreversible exhaustion of 'natural capital', whereas industrialized economies show internal improvements towards dematerialization but they employ more materials from abroad. The metabolism of rich industrial societies including parts of China would be economically unsustainable if the prices of imported essential bulk commodities such as the fossil fuels became too high.

Not only the exhaustible resources, also some renewable resources are exploited at excessive rates (Ecuador's deforestation rate is one of the highest in Latin America, and the rate of clearance of vegetation could mean a total loss by the year 2050), raising the probability that, like oil, they may at some point vanish. Mangrove coverage of the coast has decreased, and its coastal protection function has also been lost. Countries like Ecuador need to consider not only the costs of local natural resource destruction but also the eventual need to import essential materials from abroad.

Extractive activities are the source of a variety of social conflicts that we call 'resource extraction conflicts'. They include the complaints because of waste disposal during the extraction processes. Pressures exerted on the environmental services upon which poor and indigenous populations depend, give rise to conflicts. One such conflict led to the remarkable court case against Chevron-Texaco claiming compensation for the socio-environmental liabilities. Also, the national and international popularity of the Yasuni ITT proposal is a sign of the increasing general awareness of the damages from oil extraction in fragile environments.

This paper has offered a brief description of ongoing resource extraction conflicts. In Amazonia, some communities have tried to stop the oil industry. There are also conflicts on shrimp exports (that destroy mangroves), tree plantations for export, and projects of open-cast mining. So, this article combines the analysis of societal metabolism with the analysis of resource extraction conflicts.

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