FACULTAD LATINOAMERICANA DE CIENCIAS SOCIALES
SEDE – ECUADOR
PROGRAMA DE DOCTORADO EN ECONOMÍA DEL DESARROLLO
CONVOCATORIA 2005 - 2008

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# PERFILES METABÓLICOS DE TRES ECONOMÍAS ANDINAS: COLOMBIA, ECUADOR Y PERÚ

MARÍA CRISTINA VALLEJO GALÁRRAGA

MARZO DE 2010

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**MARZO DE 2010**

***El fin de una etapa marca un nuevo comienzo,***
***este inicio es junto al ángel que ilumina mis días…***

## AGRADECIMIENTOS

Siento enorme gratitud por todas las personas que hicieron posible el desarrollo de esta investigación. En primer lugar mi familia y mis amigos, cuyo apoyo constante ha alentado el avance de este proceso. En particular agradezco a mis amados padres y a mi hermano, también a mis entrañables amigos Wilson Pérez, Alicia De La Torre y Marcela Aguirre, quienes a pesar de la distancia no dejaron de acompañarme. En segundo lugar, el Profesor Joan Martínez-Alier, quien ha colaborado incansablemente en esta investigación, enriqueciendo sus resultados y compartiendo sus conocimientos. Asimismo, a quienes revisaron versiones previas de este trabajo, los profesores Nina Eisenmenger, Jesús Ramos-Martín y Helga Weisz. Finalmente, agradezco a todas las instituciones que dieron soporte financiero para desarrollar esta investigación: la Facultad Latinoamericana de Ciencias Sociales de Ecuador, la Fundación Carolina de España, el Instituto para las Ciencias y Tecnologías Ambientales de la Universidad Autónoma de Barcelona.

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**PREFACIO**

Esta tesis es el resultado de mi trayectoria académica en la Facultad Latinoamericana de Ciencias Sociales, FLACSO-Ecuador, así como también en el Instituto de Ciencias Tecnológicas y Ambientales de la Universidad Autónoma de Barcelona, y el Instituto de Ecología Social del IFF de Viena. Luego del programa de maestría cursado durante el período 2003-2005, me incorporé en el primer Programa de Doctorado en Economía de Desarrollo que inició en ese mismo año en la FLACSO. Fueron tres años de estudios formales de la Economía, particularmente enriquecidos con los últimos cursos que dictaron profesores de renombre internacional en el campo de la economía ortodoxa y heterodoxa, quienes vinieron a Quito gracias a las gestiones del Profesor Wilson Pérez, que en aquel entonces conducía el programa. Ciertamente, también lo aprendido durante la maestría con el Dr. Fander Falconí y el Dr. Joan Martínez-Alier en economía ecológica me ayudó a mantener una visión crítica de la economía. Es por ello, que esta etapa de estudios que ahora culmina, se centra en el estudio de la economía desde una perspectiva ecológica. En este trabajo se extiende el camino emprendido con un primer análisis de la estructura biofísica de la economía ecuatoriana (1980-2003) que presenté en el año 2005 y se publicó en 2006. Los avances metodológicos en este campo permiten hacer en la actualidad medidas más precisas de los flujos de materiales y analizar de mejor forma las presiones ambientales vinculadas al uso de recursos para fines económicos.

La tesis doctoral comprende un análisis de flujos de materiales desde 1970 al 2007 en Ecuador, Colombia y Perú para introducir ese método de estudio del metabolismo de la sociedad en economías latinoamericanas (junto con los trabajos de otros investigadores en otros países de la región). En segundo lugar, la tesis confiere una base de datos que permite contestar preguntas tales como si la economía se desmaterializa al crecer y analizar las tendencias de su intensidad material, su grado de dependencia de recursos agotables, las trayectorias del comercio exterior, los balances de comercio físicos que son negativos y el deterioro de los términos de intercambio, sobre los indicadores de la transición socio-ecológica hacia la industrialización, sobre los conflictos sociales que surgen de la extracción de materiales, sobre la posible “maldición de la abundancia” que afecta a nuestras economías. Incluyo también un análisis comparado de tendencias económico-ecológicas en una muestra de 151 economías. Me habría gustado abundar más en temas de contabilidad macroeconómica-ambiental y de política macroeconómica incluida la "enfermedad holandesa" y la dolarización.

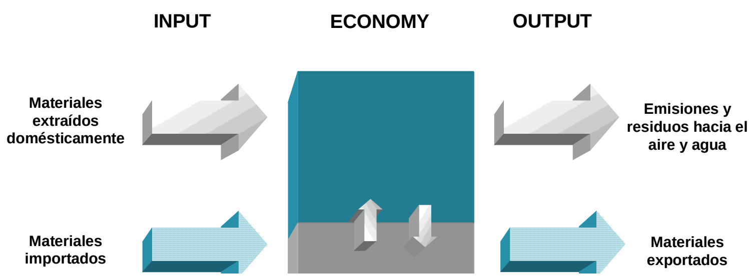
La tesis está escrita en español en algunos capítulos (esta introducción, las conclusiones y uno de los artículos) y en inglés en otros. Esta rareza se debe a que dos capítulos están en trámite avanzado de publicación (habiendo sido aceptados con revisiones aquí ya incorporadas) en Ecological Economics y en el Journal of Industrial Ecology.

María Cristina Vallejo.

## INTRODUCCIÓN

Esta investigación recoge una nueva forma de entender la presión de la economía en la naturaleza, a través del concepto de metabolismo de las sociedades, que extiende la noción de perfil metabólico característico de los organismos vivos al funcionamiento de las economías. En esta tesis doctoral se estudia la dimensión ambiental según el tamaño y la composición de los flujos de materia que se movilizan para hacer efectiva la producción, el consumo y el intercambio de materiales con otras economías. Tal como los sistemas biológicos toman sus nutrientes, carbono, oxígeno, agua y otros productos y servicios ambientales de la naturaleza para funcionar, las economías también se alimentan de la materia y energía que son insumos productivos, sea que se extraigan del ambiente doméstico o se importen. Luego de procesar estos recursos, tanto en la economía como en los sistemas biológicos se generan desperdicios que se depositan en el medio ambiente, aunque los sistemas biológicos suelen aprovechar los residuos materiales. En la economía cierta fracción puede reciclarse, reutilizarse o simplemente se acumula en la forma de stocks que se convertirán en residuos en el futuro (Ayres y Simonis 1994; Fischer-Kowalski 1998). Estas analogías entre los sistemas biológicos y sociales permiten mostrar a la economía en un modelo sistémico simple, que desde la dimensión material muestra intercambios entre la economía y el ambiente.

**Gráfico 1: Modelo sistémico de la economía**




Fuente: Eurostat (2007), elaboración propia

Estos intercambios socialmente organizados entre los sistemas socioeconómicos y su ambiente, y también entre diversas economías, típicamente se representa a través de un modelo sistémico de intercambio de flujos de materia y energía, que se representa a través del gráfico 1.

La contabilidad de los flujos de materiales es una propuesta metodológica que forma parte de los sistemas satelitales de cuentas de recursos naturales, y ha sido abordada desde la ecología industrial y la economía ecológica con el objeto de cuantificar estos procesos. Los indicadores de uso de materiales son medidas de la presión ambiental de la actividad económica, y de acuerdo a Van der Voet et al. (2008) también son signos indirectos de impactos ambientales, pues las cadenas extractivas y productivas implican a su vez una cadena de daños relacionados con el procesamiento, el transporte, el intercambio, el consumo y la disposición de residuos en la naturaleza. Pero eso no significa por supuesto que cada tonelada de materiales extraída tenga el mismo efecto ambiental.

Antecedentes a este trabajo en el caso del Ecuador son las investigaciones de Fander Falconí en una comparación de indicadores de sustentabilidad fuerte y débil (Falconí 2002), y también un trabajo conjunto con Jesús Ramos-Martín que compara a Ecuador y España en una evaluación económica-ambiental integrada con múltiples escalas, es decir, usando paralelamente información de varias disciplinas (Falconí y Ramos-Martín 2003). Asimismo, varios trabajos de Joan Martínez-Alier, de Anamaría Varea y co-autores, de Guillaume Fontaine y sus alumnos, y diversos informes oficiales o de grupos ambientalistas, que han abordado el estudio de conflictos socio-ambientales en el territorio ecuatoriano. Los estudios de historia económico-ambiental de Carlos Larrea han influido también en la presente tesis. En el caso de Colombia, los trabajos sobre comercio exterior de Pérez-Rincón (2006, 2008) son los antecedentes en esta tesis, aunque él no estudió todavía en esos trabajos el consumo doméstico de materiales sino solamente la exportación e importación de materiales. Para Colombia, aportamos en co-autoría con el Dr Pérez-Rincón de la Universidad del Valle en Cali, la contabilidad completa de flujos directos de materiales y también un nuevo estudio de conflictos por extracción de recursos. En el caso de Perú, una investigación de maestría de Silva

(2007) fue la primera exploración de las cuentas físicas de materiales para esta economía. En esta tesis hemos ampliado el horizonte temporal abarcando muchos más años y corrigiendo resultados para Perú al mejorar los métodos aplicados. Russi et al. (2008) resumieron y analizaron algunos trabajos comparando los casos de Ecuador y Perú con información disponible para México y Chile.

En esta tesis, añadimos la contabilidad de Colombia entre 1970 y 2007 en un artículo aceptado para publicación en el *Journal of Industrial Ecology*, ampliamos el estudio anterior sobre Ecuador (Vallejo 2006a, b) extendiendo el periodo analizado, mejorando los datos y añadiendo un estudio de conflictos ambientales causados por el creciente metabolismo social (en un artículo aceptado para publicación por *Ecological Economics*) y, finalmente, aportamos un tercer capítulo (todavía no enviado a ninguna revista) comparando los datos de Colombia, Perú y Ecuador con datos a escala mundial, modelizando los determinantes de la extracción y uso de materiales para una muestra de 151 países, y concluyendo que no se observa una "curva de Kuznets ambiental" ni en la extracción ni en el consumo material.

Las estimaciones de los flujos de materiales de Colombia, Ecuador y Perú, se han hecho para un período de casi cuarenta años: 1970-2007, un periodo de alto crecimiento demográfico y de vaivenes en el crecimiento económico. El estudio del metabolismo material de estas sociedades extractivas es interesante no sólo como una contribución económico-ecológica sino también como complemento para las Cuentas Nacionales. Por ejemplo, en Ecuador, el Banco Central y/o la SENPLADES podrían continuar las series aquí presentadas en los años venideros, y eso se podría hacer también a nivel regional. La CEPAL debería emprender esas contabilidades.

Esta tesis doctoral por tanto no solo aporta una investigación laboriosa y novedosa de la contabilidad de flujos de materiales para uso doméstico o exportación en estos tres países, sino que aborda otros grandes temas, a saber: el debate sobre la sustentabilidad de las economías y la desmaterialización absoluta o al menos relativa al PIB, la influencia del crecimiento demográfico en el uso de materiales, las transiciones socio-ecológicas históricas y futuras, el comercio ecológicamente desigual, las políticas económicas que puedan guiar las economías hacia una mayor sustentabilidad ambiental y por último los lazos entre el metabolismo social y los conflictos por extracción de recursos. Precisamente, un acicate para reducir el uso de materiales es disminuir los pasivos ambientales y sociales, que esas protestas evidencian.

El propósito general de esta investigación es estudiar el metabolismo social de tres economías andinas—Colombia, Ecuador y Perú—a través de la construcción de indicadores de flujos directos de materiales. A partir de esta base de información se exploran cinco preguntas generales de trabajo. En primer lugar, se analizan las intensidades materiales absolutas y relativas para determinar si es que ¿estas economías se desmaterializan al crecer? En segundo lugar, se analiza si es que ¿se pueden explicar los conflictos ecológico-distributivos a partir de los flujos de materiales? En tercer lugar, se comparan las tendencias económicas con los patrones de uso de materiales y los conflictos ecológico-distributivos, preguntándonos si ¿es posible verificar la llamada "maldición por la abundancia de recursos naturales" en estas economías? En cuarto lugar, al combinar los indicadores de flujos de materiales, con indicadores de uso de energía y del uso del suelo, se investiga si ¿existe una transición socio-ecológica en estas economías? Finalmente, se exploran las tendencias de los flujos de comercio para analizar si ¿se verifica un intercambio ecológicamente desigual?

Para el estudio del metabolismo de las sociedades existen diversos métodos. La evaluación de los flujos de materiales y de energía son los métodos más ampliamente utilizados, pero también los cálculos del "agua virtual" y HANPP—la apropiación humana de la producción primaria neta—se pueden utilizar. Por una parte, como agua virtual se cuantifica la cantidad de agua empleada en los procesos industriales y agropecuarios de producción de bienes y servicios, incluyendo el agua contenida en esos productos (Allan 1993, 1994, 1998; Hoekstra 2003; Hoekstra y Chapagain 2007a,b). Por otro lado, la HANPP mide la proporción entre la biomasa usada por los seres humanos y la cantidad potencial de biomasa que sería generada en ausencia de humanos. Es un indicador de pérdida de biodiversidad, ya que al crecer la HANPP seguramente disminuye la biodiversidad, pero también se puede usar para analizar conflictos relacionados con recursos (Haberl 1997; Haberl et al. 2001; Imhoff et al.

2004; Krausmann 2001; O'Neill et al. 2007; Rojstaczer et al. 2001; Vitousek et al. 1986; Whittaker and Likens 1973; Wright 1990). A fin de explorar las preguntas de trabajo planteadas en este documento, es necesario comprender con claridad al menos cuatro definiciones importantes:

a. Desmaterialización
b. La "maldición de la abundancia de recursos naturales"
c. Las transiciones socio-ecológicas
d. Intercambio ecológicamente desigual

La desmaterialización se refiere al proceso de satisfacer las funciones de la sociedad con un uso decreciente de materiales en el tiempo (Cleveland y Ruth 1998).

La llamada "maldición por la abundancia de recursos naturales", tiene lugar cuando esta abundancia en lugar de generar desarrollo y crecimiento económico, condena a las economías a una situación de estancamiento y conflictos sociales (Auty 1993; Gavin y Hausmann 1998; Sachs y Warner 1995, 2001).

Las transiciones socio-ecológicas implican un proceso continuo de cambio social, en donde la estructura de una sociedad y las relaciones ambientales que esta sociedad ha establecido se transforman (Fischer-Kowalski y Haberl 2007; Krausmann et al. 2007; Schandl et al. 2009).

Finalmente, el intercambio ecológicamente desigual que se define a partir de las asimetrías en el comercio internacional que prevalecen entre las llamadas economías del Norte (o el centro en términos de del intercambio desigual que propuso Prebisch en la década de los años cincuenta) y el Sur (la llamada periferia). Por un lado, muchas economías del Sur muestran una salida neta de materiales domésticos para cubrir la demanda externa de las economías del Norte, cuyo funcionamiento metabólico depende de estas fuentes de recursos. Estos productos se obtienen a partir de procesos extractivos que deterioran el ambiente y generan presiones en los recursos renovables y no renovables. Por otro lado, las asimetrías en el valor de los bienes que la periferia importa y exporta, intensifican la explotación de recursos naturales porque cada vez requieren de la exportación de mayores cantidades de materiales a fin de obtener los ingresos suficientes para adquirir las mismas cantidades de bienes importados. En efecto, mientras más energía disponible (o potencial productivo) ha sido disipado para producir los bienes y servicios finales, los precios de la producción son más altos, al tiempo que no se reconocen externalidades sociales y ambientales.

En términos de disciplinas, esta tesis es una contribución a la economía ecológica, a la vez que resulta también relevante para la macroeconomía (con temas tales como la "maldición de la abundancia de recursos naturales", la curva de Kuznets ambiental y los términos de intercambio en el comercio exterior), para la ecología industrial (que analiza flujos y reciclaje de materiales a diversas escalas) y para la ecología política (que analiza conflictos ecológico-distributivos), a la vez que elabora nuevas estadísticas y emplea algunos métodos econométricos. La tesis discute también políticas económico-ambientales para lograr economías más sustentables.

# 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.***

***Keywords:*** Material flow accounting, ecologically unequal exchange, extractive economies, resource extraction conflicts, societal metabolism, socio-ecological transition.

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[1] This document has been accepted for publication in Ecological Economics.

## 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.

## 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), Perez-Rincon (2006), Russi et al. (2008), Vallejo (2006a,b), Vallejo et al. (2010).

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[2] enables numerous double-checks for data quality, coherence and consistency; some flows,

[2] 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).

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.[3] 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.

**Table 1: Definitions and data sources**

| *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). |

*Sources:* Eurostat (2001, 2002, 2007) and author's elaboration.

[3] 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.

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.

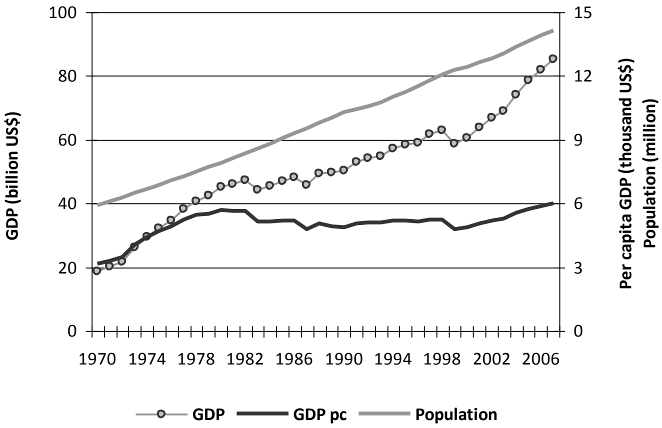
In the case of wood harvested, although illegal forest clearance and the domestic consumption of fuel wood directly collected by rural households introduce some uncertainty in statistics, FAO is a reliable data source. The WB (2006) calculates that 70% of the total production comprises illegal extraction. 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 mines.[4] 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.[5]

## 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. Figure 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.

**Figure 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), CELADE (2009)

[4] 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).

[5] 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.

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)*

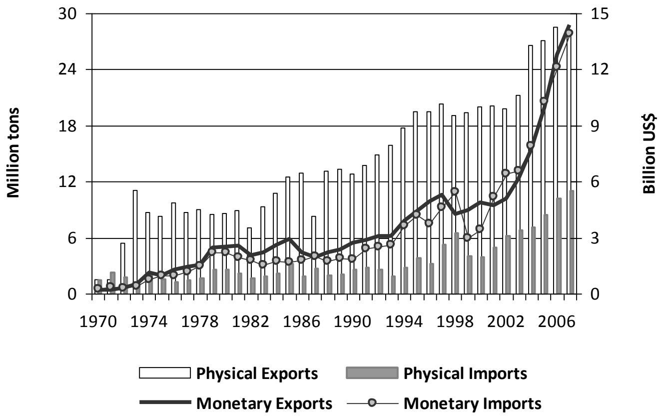
The physical trade balance (PTB) is calculated by subtracting export flows (X) from import flows (M): opposite to the widely known monetary trade balance (X - M). Following the logic that monetary and physical imports and exports flow in opposite directions: imports (exports) mean money leaves (come 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 figures 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.

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.

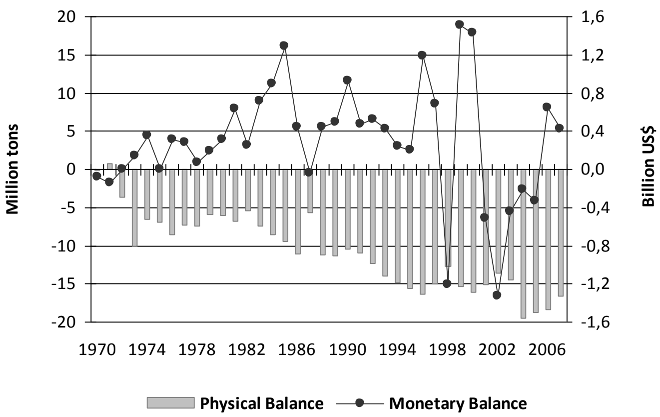
The balance of payments measures the monetary flows generated by international trade (the commercial balance), migrants' remittances, foreign direct investment, and external funding (the capital balance). In particular, it provides an approximation of the amount of currency available to carry out economic 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.

**Figure 2: Physical and monetary trade flows**




*Sources:* Author's estimations

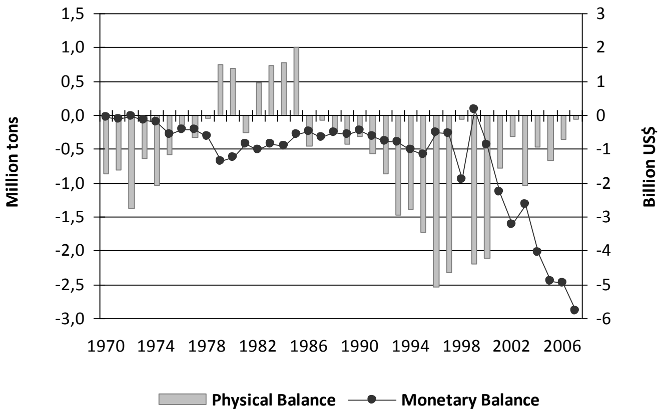
**Figure 3: Trade balances**




*Sources:* Author's estimations

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 figure 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).

**Figure 4: Trade Balances - Non-petroleum commodities**



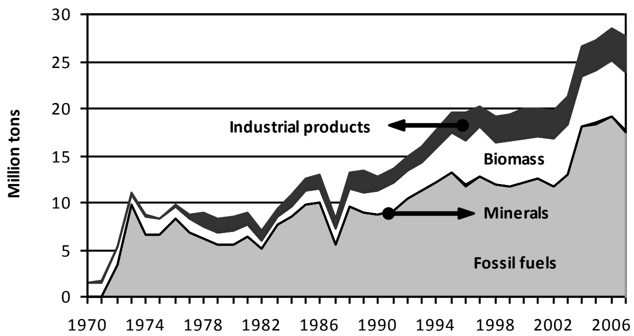

*Sources:* Author's estimations

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 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 figure 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.

**Figure 5: Material Exports**




*Sources:* Authors estimations

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 el 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.

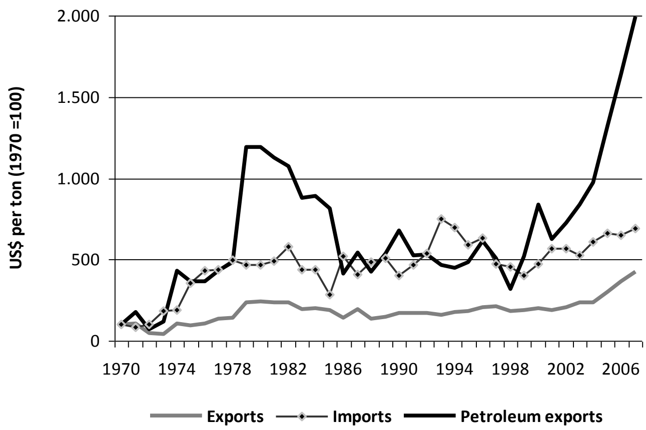
### *3.2 The Terms of Trade*

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 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.

**Figure 6: Unit values of trade**




*Source:* Author's estimations

Unit values (US$ per kilogram) of imported and exported materials (base year 1970) are presented in figure 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.

**Table 2: Metabolic profile of Ecuador compared to agrarian and industrial socio-ecological regimes.**

| *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
*Sources:* (a) Krausmann et al. (2008), (b) author's estimation, (c) WB (2010), (d) FAO (2010).

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. (2010) 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 (Falconi 2002, Falconi 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).

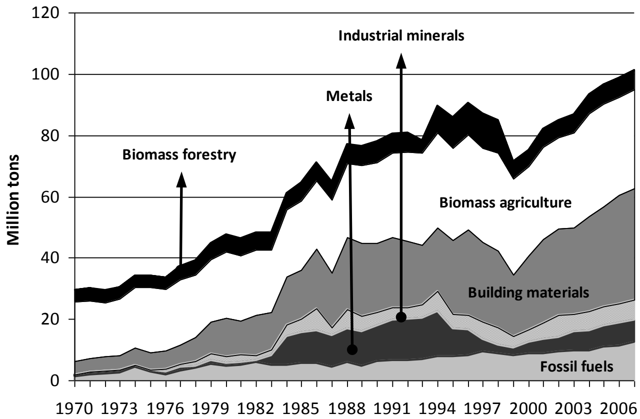
The most relevant factors to explain the growth of building materials consumption in the country are the large scale urbanization process—only 34% of the population is now located in rural districts—and the recent expansion of housing financed by migrant's remittances.

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.

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 figure 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.

**Figure 7: Domestic material consumption**




*Source:* Author's estimation

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.

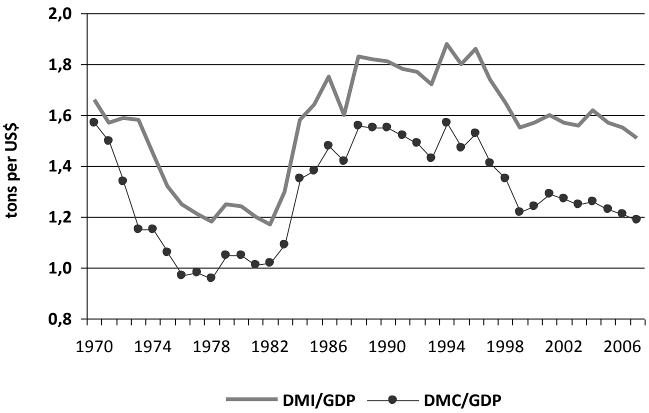
The use of materials measured in terms of per capita DMC increased only by a factor of 1.5 over nearly forty years. Population expanded by a factor of 2.3—although the rate of population growth is now declining. Per capita agriculture biomass consumption—mainly associated to the population’s nutritional 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 figure 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.

**Figure 8: Material intensity of Ecuador**




*Note:* GDP figures in PPP dollars at 2005 constant prices
*Source:* Author's estimation

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 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.

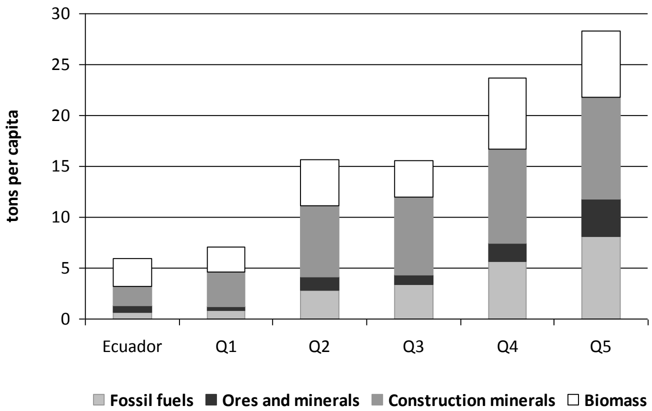
According to the government, Ecuador is ready to make this sacrifice provided there is an international compensation which covers at least half the foregone revenue. At the other extreme there are plans to take out all the oil reserves (Ecuador has passed peak oil already) as far as the market demands, 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?

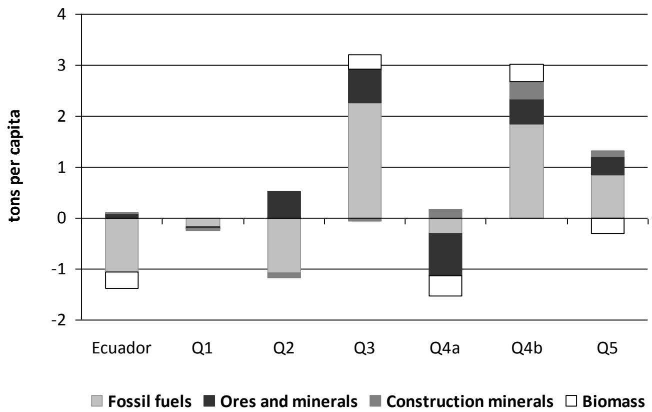
The position of Ecuador in the socio-metabolic profile on a global scale is analyzed here. As in Krausman et al. (2008), important differences are identified between developing and developed economies. The relevant finding is that among low-income economies there are also broad margins in the material 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.

**Figure 9: Comparison of metabolic profiles in terms of DMC**




*Sources:* Krausmann et al. (2008) and author's estimation

**Figure 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

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) in the year 2007. 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 figures 9 and 10.

### 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.

## Table 3: Resource extraction conflicts regarding bulk commodities in Ecuador

| *Commodity in conflict* | *Period and location* | *Main actors* | *Social and natural resources affected* |
|---|---|---|---|
| Oil | 1911-1960<br>CoA, Peninsula of Santa Elena | MC (Anglo-British Petroleum), State, LC | Water, soil, air, biodiversity, forest, human health, traditional knowledge. |
| | 1970-2001<br>Am, Aguarico canton-Orellana Prov. | MC (Texaco), NC (CEPE and Petroecuador), LC | |
| | 2003-2007<br>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<br>HlA, Macuchi, Cotopaxi Prov. | MC (Cotopaxi Exploration Company-SADCO), State, LC | Soil, water, biodiversity, agriculture |
| | 1975-1981<br>HlA, Toachi river, Pichincha Prov. | NC (Compañía Minera Toachi), State, LC | |
| | 1995-2008<br>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, food security. |
| Sawlogs and veneer logs | Since 1972<br>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<br>HlA, Cotopaxi and Pichincha Provs. | NC (Acosa, Novopan, etc.), settlers, LC | |
| Wood for paper pulp export: eucalyptus | Since 1990s<br>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

*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).

## Table 4: Resource extraction conflicts regarding "preciosities" in Ecuador

| *Commodity in conflict* | *Period and location* | *Main actors* | *Social and natural resources affected* |
|---|---|---|---|
| Gold, and silver | 1904-1950<br>CoA, Portovelo-Zaruma, El Oro Prov. | MC (South American Development Company-SADCO), S, LC | Water, soil, air, human health. |
| | 1941-1950<br>HlA, Macuchi, Cotopaxi Prov. | MC (Cotopaxi Exploration Company-SADCO), S, LC | |
| | 1950-1978<br>CoA, Portovelo-Zaruma, El Oro Prov. | NC (CIMA), S, LC | |
| | 1975-1981<br>HlA, Toachi river, Pichincha Prov. | NC (Compañía Minera Toachi), S, LC | |
| | 1978-1992<br>CoA, Portovelo-Zaruma, El Oro Prov. | NC (State's CIMA), S, LC | |
| | 1980s-1990s-2000s<br>Am, Nambija, Zamora Chinchipe Prov.<br>CoA, Portovelo-Zaruma, El Oro Prov.<br>HlA, Ponce Enriquez, Azuay Prov. | Artisanal miners (1980s), miners' associations (1990s), NC (Minpalca in Ponce Enriquez, Andos in Nambija), MC (IamGold in Portovelo-Zaruma), S, 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), S, LC | |
| | Rio Blanco Project, HlA, Molleturo, Azuay Prov. | MC (International Minerals Company: 650 thousand ounces of gold and 4.2 million ounces of silver), S, LC | |
| | Quinsacocha Project, HlA, Giron, Azuay Prov. | MC (IamGold: 3 million ounces of gold), S, LC | |

**Table 3: Resource extraction conflicts regarding bulk commodities in Ecuador**

| *Commodity in conflict* | *Period and location* | *Main actors* | *Social and natural resources affected* |
|---|---|---|---|
| Shrimp | Since the 1980s<br>CoA, Muisne, Esmeraldas Prov. | Small and middle producers, LC | Mangroves, water, labor options for local communities |
| | Since the 1980s<br>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<br>HlA, Pichincha Prov. | NC (Jardines del Ecuador, Florexport), LC | Water, soil, human health, food security |
| | 1980s<br>Pichincha, Imbabura, Cotopaxi, Chimborazo, Azuay, Cañar Provs. | NC (Agroflora, Empagri, Florisol, Agricola Pazcor, Florequisa, El Rosedal, Rosas del Ecuador, Arbusta) LC | |

*Notes:*

HlA: Highland areas
MC: Multinational Companies
CoA: Coastal areas
Am: Amazonia

NC: National Companies
LC: Local communities
S: State
Prov: Province

*Sources:* Accion Ecologica (2007), CME (2009), Espinel (2001), Guerra (2003), Hernández et al. (2007), Human Rights Watch (2002), Sandoval (2001), Vásquez (2006), Olmos and Torres (2009).

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).

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 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.

# METABOLIC PROFILE OF THE COLOMBIAN ECONOMY FROM 1970 TO 2007[6]

**Maria Cristina Vallejo[7], Mario A. Perez-Rincon[8], Joan Martinez-Alier[9]**

## Abstract

*This article characterizes the societal metabolism of the Colombian economy identifying the main factors of natural resources use, overuse or exhaustion. The environmental sustainability of a country depends to a large extent on the size of the economy compared to the available resource base. Material flows indicators provide an assessment of size or scale of economies. Direct material flow indicators are used to analyze the ecological dimension of economic activity in the period 1970-2007. Some resource extraction conflicts are briefly described in the light of material flow analysis. Foreign and domestic demand promotes increasing extraction and export of domestic natural resources, this is sometimes related to an irreversible deterioration of the local environment. The concept of "ecologically unequal exchange" with the rest of the world is analyzed in this context. Colombia has a large growing negative Physical Trade Balance, whereas per capita use of materials is still about half of the industrial countries average.*

**Keywords:** Ecologically unequal exchange, Material flow accounting, Material intensity, Resource curse, Resource extraction conflicts, Societal metabolism.

## 1. Introduction

This article discusses material use patterns of the Colombian economy between 1970 and 2007. The concept of societal metabolism (Ayres and Simonis 1994; Fischer-

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Kowalski 1998; Fischer-Kowalski and Haberl 1993, 1997) is the central foundation of the analysis. It provides a biophysical reading of the economy, and explores environmental pressures and conflicts related to the extraction of resources and the production of wastes.

A systematic analysis of material flows is a necessary condition to account for the environmental dimension of the economies, which is omitted in conventional macroeconomic indicators. It helps to understand the linkages between the course of development and material use patterns, quantify progresses towards a sustainable use of resources by improvements in the material efficiency (or reductions in the material intensity), analyze trends in environmental pressures related to economic activities, and recommend policy alternatives. The study of societal metabolism is connected in this article to Political Ecology, a field that studies conflicts on property rights and communal resource management, and in general conflicts on resource extraction and waste disposal (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). This article attempts therefore to bridge the gap between Industrial Ecology and Political Ecology.

Societal metabolism is a conceptual tool, the starting point of which is a comparison of the functioning of biological and social systems. Biological systems depend on the environment for vital resources such as water, carbon dioxide, nutrients, and other essential services like the ability to dispose of wastes. In a similar way, socioeconomic systems depend on the environment to operate. The economy requires materials from the domestic environment to produce goods and services, besides foreign materials imported. Once consumption takes place, these flows become outflows to the environment. They are disposed in the form of material residues, emissions, dissipative uses or losses, or to some extent they could be reused, recycled or simply accumulated as societal stocks.

Taking these ideas as a foundation, a simple systemic model has been used here. In this model, the economy is an open system embedded in its physical environment, which means that socioeconomic systems maintain socially organized material (and energy) exchanges with their environment (Eurostat 2007). Such a biophysical understanding of a socioeconomic system is commonly referred to as societal metabolism. Material Flow Accounts (MFA) and the derived indicators are consistent compilations of the overall material inputs into national economies, the changes of material stocks within the economic system and the material outputs to other economies or to the environment (Eurostat 2007).

This article takes a second step on the compilation of MFA of the Colombian economy. The first contribution was the construction of the Physical Trade Balance for the period 1974-2004 (Perez-Rincon 2006, 2008). The present study incorporates direct material flows of domestic use, and expands the analytical framework from 1970 to 2007. There will be a marked change in world extraction and trade of materials in 2008-2009 because of the international crisis. This article gives a baseline to chart the future pattern of the Colombian economy in the light of the economic crisis and also of the rapid decline in the rate of population growth. A novelty of the analysis is the attempt to trace links between Colombia's metabolic profile (Schandl and Schulz 2000)—domestic and external—and resource extraction or waste disposal conflicts.

On the environmental sustainability of this economy, at least two questions are addressed. One is related to specialization patterns. As other "extractive economies" (Bunker 1985), Colombia has a history of intensive exploitation of natural resources. Is this economy increasingly specialized in exploiting resources for export rather than for domestic use? A second question concerns the so called "resource curse" (Auty 1993; Gavin and Hausmann 1998; Sachs and Warner 1995, 2001). Could natural resource abundance determine economic stagnation and conflicts in the country, rather than growth and development?

This article is organized as follows. After the introduction, an explanation of the methodology is provided. The third section comprises a characterization of the Colombian economy, introducing some aspects relevant for understanding socio metabolic patterns. Results of the study are presented in the fourth section, which is divided in sub-sections to analyze in detail the MFA and the derived indicators. We also compare the economy of Colombia with other economies in terms of material intensities. In addition, some ecological distribution conflicts related to extractive activities are briefly described. The last section presents the conclusions and some policy implications derived from the results.

## 2. Methodology and information sources

### 2.1. Definitions and methods

This article does not modify the GDP accounts but introduces separate, “satellite” accounts for Colombia with physical indicators: Domestic Extraction (DE), Direct Material Input (DMI), Domestic Material Consumption (DMC), besides an updated Physical Trade Balance (PTB), and material intensities of the economy.

DE is the purposeful extraction or movement of natural materials by humans or human-controlled technology (i.e., those involving labor). Used flows are inputs extracted from the environment to be employed in the economy, whereas unused flows are not intended for economic purposes. It means that used materials have acquired the status of a “product” (Eurostat 2001, 2007). The general categories of materials are: biomass, building materials, industrial minerals, metal ores, and fossil fuels.

DMI comprises domestic and foreign inputs for economic activities: DE plus physical imports (M). DMC measures the fraction of all materials that remains in the economic system until released to the environment. It is the difference between DMI and material exports (X). Finally, the PTB is defined contrary to the monetary trade balance—M-X, taking into account the fact that money and goods move in opposite directions in economies, and that international trade becomes a mechanism to transfer environmental pressures across frontiers. A negative PTB means larger exports than imports, in tons.

MFA computed in this article are based on methodological guides of EUROSTAT (2001, 2002, 2007).[10] More recently, OECD (2008) has become an obligatory methods source. These guides provide not only fundamental definitions and conceptual principles but also practical procedures for the accounting and reports. The only omitted aspects are those related to unused extraction, indirect flows or sectoral disaggregation of material flows; which are not yet standardized.

### 2.2. Data sources and reliability

The time series of the material categories identified are based on statistical data compiled by international organizations as detailed in table 1. This information was originally collected by national statistical offices 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 activities in agriculture and forestry, hunting, grazed biomass, forage, 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.

Illegal crops of coca, marijuana, and opium poppy can conceptually be linked to direct MFA. The lack of consistency between different sources, however, makes it difficult to generate reliable annual estimates.[11] In addition, these flows are not significant in terms of tonnage—less than 0.3% of DE of primary crops. Their manufactures (cocaine and heroin) are important items in the economy: about 40% of export revenues between 1980 and 1995. They are what Immanuel Wallerstein called “preciosities” (Hornborg et al. 2007) in the context of colonial trade, because of their high price per unit of weight (like gold or pepper). Illicit crops have high prices because of prohibition.

[10] First publications on MFA were developed at a national scale for Austria (Steurer 1992), Japan (MEGJ 1992), and Germany (Schutz and Bringezu 1993). Two subsequent harmonization efforts were the Concerted Action “ConAccount” (Bringezu et al. 1997, Kleijn et al. 1999), and the internationally comparable indicators from the World Resources Institute (Adriaanse et al. 1997, Matthews et al. 2000).

[11] Estimations presented by Steiner (1997) show that around three thousand tons of coca were harvested in 1980, and 30 in 1990. Bernal (2003) reports 115.8 in 2000, and the USDS (2008) registers more than 154.1 in 2006. Regarding marijuana and opium poppy, Steiner presents export figures: 3.9 thousand tons of marijuana and 0.02 of opium poppy until 1995.

In the case of wood harvested, although illegal forest clearance and the domestic consumption of fuel wood directly collected introduce some uncertainty in statistics, FAO is a reliable data source. The WB (2006) calculates that 42% of the total production comprises an illegal extraction. According to the official reports from ITTO (2008), legal production of wood in 2007 was 3.4 million m3, which determines a total extraction of 4.4 Mt including the illegal activities (assuming a wood density coefficient of 0.85 tons/$m^3$).

**Table 1: Data sources**

| Category of material | Description | Sources |
|---|---|---|
| Trade | Import and export data classified by the level of processing (ISIC Rev. 2) and the main material component. | UNSD (2009a) compared to DANE (2009a). |
| 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 (2009a). |
| Grazed biomass | Demand for forage of livestock units. | FAO (2009a). |
| Forage | Crop residues of sugar cane and cereals used as forage. | FAO (2009a); OLADE (2007). |
| Forestry | Wood harvested from forests, plantations, or agricultural lands: fuel wood, roundwood and wood roughly prepared. | FAO (2009a). |
| Fishing | Captures of fish, crustaceans, mollusks, and aquatic invertebrates. | FAO (2009a). |
| 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);<br>UNSD (2009b); USBM (2009). |
| Fossil fuels | Production of fossil fuels. | OLADE (2007) compared to OPEC (2007). |

*Source:* Authors' elaboration

Biomass from hunting is not accounted for because of the lack of regular reports disaggregated at this level, and the short contribution of volumes obtained through estimations.[12]

Comparisons of different international data sources and studies determine an underestimation in building materials statistics from the USBM. These accounts are calculated by following a recently proposed method (Krausmann et al. 2009), which is based on cement and bitumen production figures.[13]

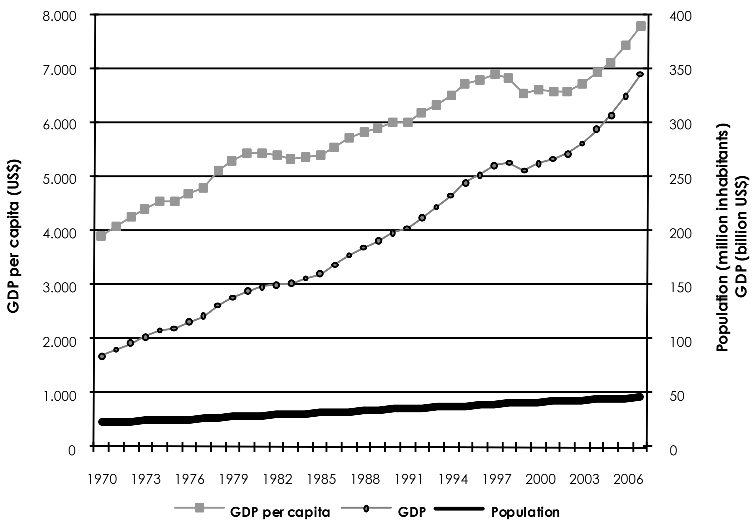
[12] Baptiste et al. (2002) present estimations of the indigenous Wuonaan's hunting: about 1.8 tons a year of biomass (mammals, reptiles, and birds). This volume (0.2 kilograms per person) extrapolated to the indigenous population of Colombia depending on hunting (about 154 thousand people), determines a total amount of 31 tons a year for the whole country.

[13] 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

### 3. The Colombian economy: An overview

Colombia occupies relatively high positions in several dimensions of the international rankings. It is the 36th largest economy in the world. Its geographical area of 1.1 million $km^2$ makes it the 25th largest country but with only 39 inhabitants/$km^2$ (WB 2010). Colombia is among the five most biodiverse countries in the world, with a great variety of ecosystems and species of both terrestrial and marine flora and fauna, which all add up to an impressive genetic wealth. With only 0.7% of the global surface area, Colombia hosts around 10% of the world's biodiversity (DNP 2007). In social terms, however, around 49.2% of the population lives below the poverty line and the country is ranked 77th in the Human Development Index, part of the group of countries with medium human development (UNDP 2010).

**Figure 1: Trends in the economy and population. Colombia (1970-2007).**




*Note:* GDP figures in PPP dollars at 2005 constant prices
*Sources:* Penn World Table 6.3 – Heston et al. (2009), CELADE (2009)

On analyzing the country's economic activity, total GDP at PPP prices in 2005 constant dollars rose at an annual rate of 3.9% from 1970 to 2007. Per capita income went from US$3 926 to US$7 790 in the same period. Although the population doubled from 22.5 million people to 43.9 (DANE 2009b), its growth rate is now quickly decreasing. The average for the period was 2%. Figure 1 shows the evolution of these variables.

produce asphalt. The rest of building materials required to different purposes are counted from the USBM.

After following the import substitution economic policy, common to most of Latin America until the early 1970s, a vision of development through external markets came to prevail. Between 1968 and 1989 economic policies supported strategic sectors, emphasizing housing and infrastructure instead of the industry, and diversification of the export base became the fundamental strategy (Ocampo 1993). From 1990, sectoral policies disappeared because of the prominence of macroeconomic stability policies, and deregulation to favor the economic openness. As result, the services sector expanded—mainly led by the financial sector—from 48% to 63% of GDP between 1970 and 2007; whereas extractive activities and manufacturing decreased in terms of share of GDP. This cannot be interpreted as a path of dematerialization because the absolute figures of MFA prove the opposite.

## 4. Material flow patterns of the Colombian economy

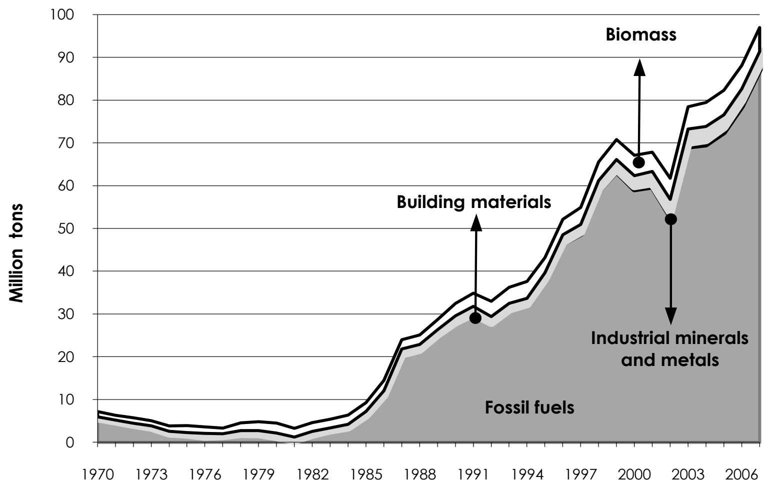
A metabolic profile of this economy is built on the base of three material flow indicators: PTB, DMI and DMC. In addition, terms of trade (TOT) describe the position of the country in trade relations with the rest of the world. Biophysical scales and dematerialization trends are compared through material intensities related to income and population figures.

### 4.1. Trade relations and inequalities

#### *4.1.1. The physical trade balance*

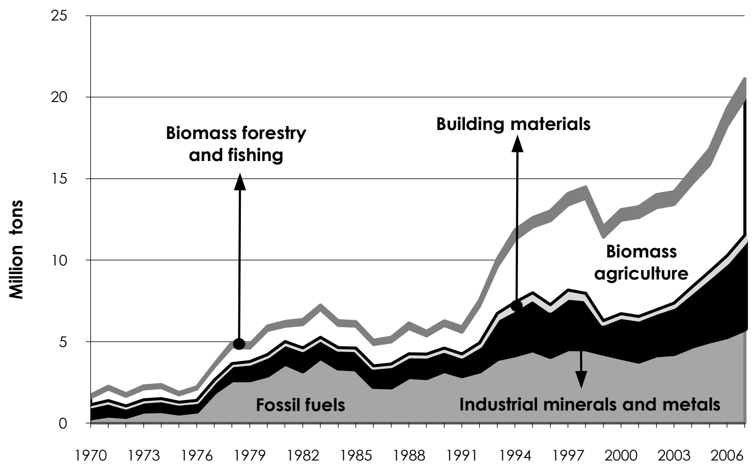
As shown in figure 2, the volume of physical exports increased notably during the period 1970-2007, from about 7 Mt (million tons) to around 97 Mt, a growth rate of 7.3%, much higher than the money growth rate of 3.9% in constant terms. A significant upwards cycle started in 1985 with the reestablishment of oil exploitation at the Caño Limon and Cusiana wells in the east, and the discovery of new coal and ferronickel exports from the large open cast mines in Cerrejon and Cerromatoso on the Atlantic Coast. Coal, which represented 70% of the total volume exported in 2007, largely explains the trends in physical exports. Participation of primary products in exports is quantified in weight at 85%. A decline in the exported amounts of fossil fuels in 2002 is related to low international prices. A significant recovery in 2003 resulted from an improvement of international prices and an expanded production capacity. Coal producers invested in transportation infrastructure, and new exploration activities were undertaken by the petroleum company.

**Figure 2: Physical Exports of Colombia (1970-2007).**




*Source:* Authors' estimations

**Figure 3: Physical Imports of Colombia (1970-2007).**

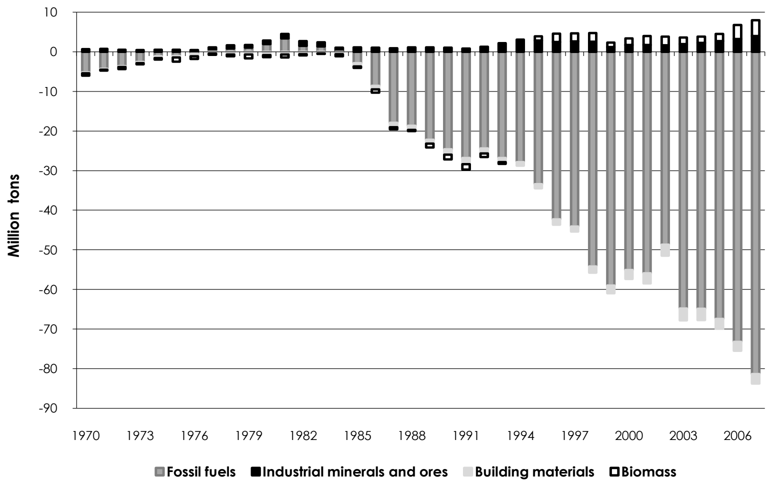



*Source:* Authors' estimations

Physical imports went from 1.8 Mt in 1970 to 21.1 in 2007, with an annual growth of 7%, as presented in figure 3. With the economic policy favorable to trade, imports were encouraged but they declined in the late 1990s due to the economic crisis, recovering after 2002. Imports are more diversified than exports, although most comprise industrialized goods (66% in 2007).

Figure 4 shows the growing PTB deficits for most of the period analyzed. The total balance for 37 years shows a deficit of 932 Mt of materials that have left the country on their way to the rest of the world, largely fossil fuels, essential for maintaining the metabolism of the importing countries.

**Figure 4: Physical Trade Balance of Colombia by material component (1970-2007).**




*Source:* Authors' estimations

Due to the relatively low price of these exported resources and to the zero prices assigned to environmental impacts, it could be said that importing countries have an ecological debt to Colombia. Most of the weight of the negative PTB comes from primary products, whereas a small positive PTB is registered for semi-manufactured goods.[14] It is a regular pattern in small economies founded on the export of raw materials domestically extracted, with a limited scope of the domestic productive chains.

[14] The PTB disaggregated by the processing level of materials was already presented in Perez-Rincon (2006).

This assessment, however, does not include indirect flows. The so called “raw material equivalents” (RME) (Eurostat 2001; Weisz et al. 2004) are not accounted for. That is, the upstream material requirements of used extraction (intermediate inputs) associated with imports or exports. Muñoz et al. (2009) determine that the Colombian deficit in the PTB doubled when the raw material trade balance was estimated, from 62 to 123 Mt. Each ton exported by Colombia needed about 1.3 tons of indirect flows that remained in the country in the form of wastes and emissions—a bigger amount in the aggregate compared with imports—whereas each ton imported required the movement of 2.9 tons of indirect flows in the country of origin.

#### *4.1.2. ¿Are terms of trade improving?*

The concept of economically unequal exchange was popularized in the 1960s by ECLAC (UN Economic Commission for Latin America and the Caribbean), and complemented with contributions from the Marxian labor theory of value. It was argued that productivity improvements of developed economies—increments in the production per worker because of technological advances—do not lead to price declines because wages increase due to the strong negotiation power of unions. On the other hand, productivity improvements in the “peripheral economies” result in lower prices because of ample supplies of labor, and because of competitions among product sellers (notice for instance that OPEC is the only successful export cartel). As result, many hours of underpaid work are embodied in primary products exported from the periphery, which are traded by few hours of well-paid work embodied in the industrial products or services imported.

This was one central argument of the Latin American so called “structuralist school”: deterioration of the TOT of primary export products (Prebisch 1950). When countries specialize in exporting goods rich in natural resources and less qualified labor, as is the case for many Latin American countries, this pattern contributes to stagnation and slow development. In this line of though, Bunker (1985, 2007) posits a structural asymmetry between “extractive economies” in the periphery and “productive economies” in the core. Industrial capitalism induces the rapid expansion of production but it is separated from extraction in spatial terms. Notice that energy cannot be recycled and materials are recycled only to some extent. Therefore, there is a need for continuous fresh supplies from the "commodity frontiers" to feed the metropolitan centres. As greater amounts and varieties of material and energy are required, extractive economies are frequently relocated, either because they have depleted their natural endowments, or because new technologies have shifted the market.

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. In order to account for such uneven development, Bunker complements the Marxian arguments with a notion of "natural values", which—like labor—are systematically underpaid by the industrial core areas to which they are transferred (Hornborg et al. 2007).

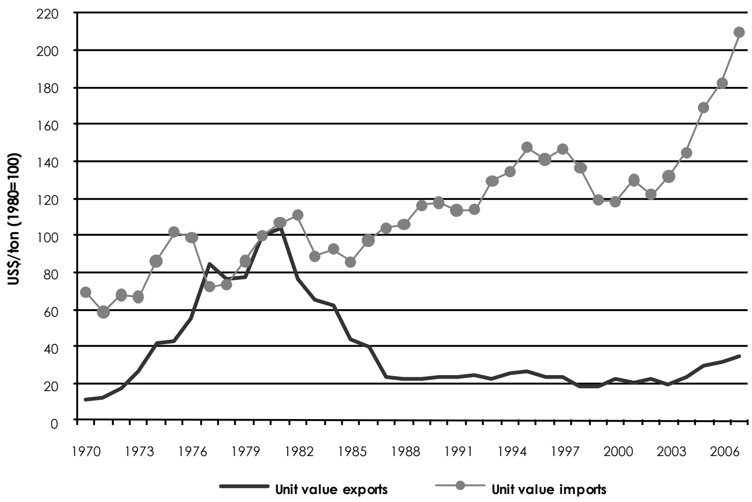
From an ecological economics perspective (Giljum and Eisenmenger 2004; Hornborg 1998; Muradian and Martinez-Alier 2001), the asymmetries in the value of imports and exports encourage intensification of natural resource exploitation to acquire the same amounts of imported goods. Moreover environmental liabilities are generated, meaning costs are not incorporated into the companies' balance sheets and into the final prices of export goods. Therefore, the South—resource intensive developing economies—not only exports its increments in productivity, but also physically drains its natural resources by sending them abroad and suffers environmental externalities due to the industrialized countries consumption patterns. All this constitutes a doctrine of "ecologically unequal exchange".

Trends in the TOT are provided in figure 5. Unit values of exported and imported products are expressed as annual indexes (base year 1980).[15] Export prices are lower than import prices, except during the coffee price peak of the 1970s caused largely by a failure of the Brazilian crop. This was followed by a substantial decline in exports unit values and a long period of stagnation until the high commodity prices registered in the 2000s—the subsequent decline since mid-2008 is out of the scope of this analysis.

[15] This base year registers the smallest differences between unit values of imported and exported materials, therefore similar magnitudes are compared in the starting point.

There were periodic improvements in TOT, sevenfold until 1977 and 1.2 times between 2003 and 2007, and periods of decline. However, if prices of metabolically essential bulk commodities (like oil, coal or ferronickel) increase too much at the world level, this slows down the economic growth of the importing countries. When 1970 and 2007 trade unit values are compared, there is no evidence of deterioration in TOT, because of the primary good price boom until 2008. Thus, export prices rose from US$102 to US$309, and import prices from US$481 to US$1 457.

**Figure 5: Unit value of foreign trade flows. Colombia (1970-2007).**




*Source:* Authors' estimations

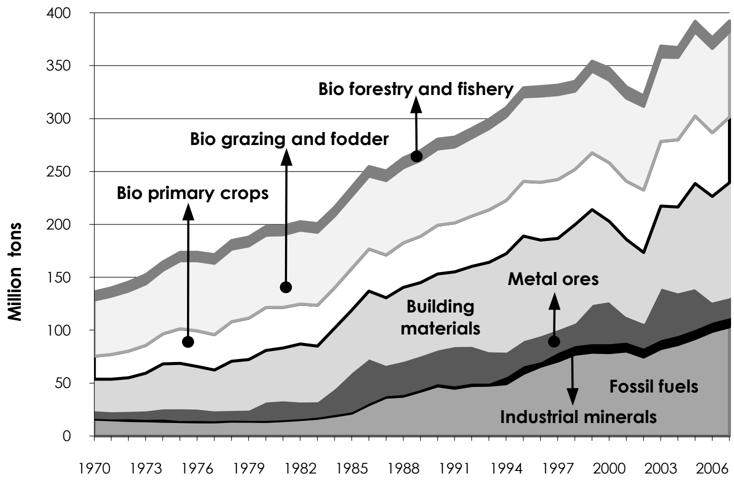
## 4.2. A domestic profile

### *4.2.1. Material Extraction and Resource Extraction Conflicts*

Historically, abundant natural resources have been exploited in Colombia. Nevertheless, there is still a notable potential for (both sustainable and unsustainable) DE in tropical forests, agro-ecosystems, grasslands, mangroves, coral reefs, wetlands, Andean forests, moors, besides the continental and maritime waters. Colombia is a large country in terms of physical space—twice as large as France—most of it covered by forests (55%), agricultural lands and pastures (38%).

Figure 6 shows DE from 1970 to 2007 by material component. A threefold increment from 136 to 392 Mt was registered. The growth rate was 2.9%, slightly larger than population growth, and lower than the economic growth of 3.9%. Consequently, the material intensity of the economy has declined.

**Figure 6: Domestic Material Extraction of Colombia (1970-2007).**




*Source:* Authors' estimations

DE of fossil fuels experienced an impressive sevenfold growth between 1970 and 2007. Current coal production, approximately 70 Mt, is mainly obtained from the Cerrejon. It is one of the largest open cast mines in the world, and it could grow much more in La Loma mine. Crude oil is the second fossil fuel exploited. In terms of weight, it is currently about 26 Mt. An unsustainable extraction of exhaustible resources, however, is not the only problem. There is also a series of associated social and environmental effects. Pollution, deforestation, lose of biodiversity, gas flaring and other severe environmental impacts, which furthermore jeopardize health conditions and possibilities of surviving of the surrounding populations.

For instance, the ancestral community of Yariguies disappeared with crude oil exploitation of the Exxon-Esso in Colombia—there are no more references of their existence after the 1920s. Likewise, the Motilones Bari communities undertook different resistance actions against Mobil's activities; however, by the late 1960s only 60% of the original population was living in less than one-fourth of the territory initially occupied (Roldan 1995). The Standard Oil Company affected about 100 thousand hectares of virgin forests, and twice this area was affected by Texaco and Mobil (Oilwatch 2001). A similar history is repeated with the U'wa communities. In 1995, the Colombian government authorized the Occidental Oil and Gas Company (OXY), operations inside their traditional territories. Although international protests supported the indigenous resistance to stop OXY activities in 2002, since 2006 the state's company Ecopetrol is operating inside the area.

As coal extraction releases toxic pollutants into the air, water and soil, it is known as the dirtiest between all fuels. The Wayuu indigenous communities, which comprise about 145 thousand people occupying 1.1 million hectares of the Guajira (DNP 1997), suffer from the impacts of open cast coal exploitation. Atmospheric pollution with coal powder is spread along 150 kilometers of railways lines crossing the indigenous territory until they reach the port, where the product is shipped for export. Wayuu's complaints emerge because of health damages, and livelihood losses due to accidental death of goats in railways lines.

The share of fossil fuels in DE increased from 13% to 29% between 1970 and 2007, whereas grazing activities diminished from 42% to 23%. Livestock units and land occupied for raising cattle show a moderated pattern of growth. The number of cattle heads increased 1.3 times, and other types of livestock almost doubled in number. Around one extra million hectares were converted to permanent meadows and pastures until 2005 (FAO 2009b), perhaps most of them primary forests. Although the majority of cattle were raised in settled grasslands of the Atlantic Coast and the East flat plains, new settlements were established on tropical primary forests (Kalmanovitz and Lopez 2006) in the South, which are also usurped to establish illegal crops.

Biomass from primary crops increased consistently by almost threefold until 2007 (22 Mt to 62 Mt). Permanent crops for export displaced some temporary crops meant for internal consumption. It was the case of cereals, roots and tubers, whose participation in primary crops extraction diminished from 19% to 13% until 2007. Sugar cane, increasingly intended for agrofuel production—as also oil palm, has maintained the highest share in primary crops throughout the years: 58% in 1970 and 64% in 2007.

Social and environmental problems related to permanent crops arise from "land grabbing" and from the intensive consumption of water—the so called "water footprint" (Chapagain and Hoekstra 2004; Perez-Rincon 2008) to the detriment of wildlife and food security, besides the increasing use of agrochemicals, pollution of water, air and soil, and health impacts on the surrounding populations. In 2007, banana and sugar cane occupied about twice more land than in 1970: 515 and 450 thousand hectares, respectively; whereas oil palm plantations, a new crop, currently surpass 165 thousand hectares.

Flower production, rather insignificant in terms of tonnage, also gives rise to environmental conflicts due to the competitive consumption of water, which is required for every stage of the processing (irrigation, fumigation and post-harvest). This conflict is worsened by water pollution and health effects because of the use of agrochemicals. Flower crops could employ on average 0.5 tons/hectare of pesticides in a year, which is eightfold higher than for potatoes, for instance.

Although biomass extracted in forestry and fishery activities is a small fraction of biomass—3% and 0.1%, respectively—both are qualitatively important because of the environmental impacts associated to their exploitation.

Colombian forests play a fundamental ecological role, not only as a carbon reservoir and home for rich biodiversity but also as protectors of vital water resources. Forest wealth, however, has deteriorated. Deforestation during the last 15 years is estimated in 47.4 thousand hectares a year (FAO 2009b).

Deforestation is mainly attributed to the expansion of pastures for grazing and agricultural activities. Other reasons are the internal consumption of wood for industrial purposes, and to some extent fuel wood as a domestic source of energy. Displacements because of the violence of the internal armed conflict and illegal crops establishment are also important sources of deforestation. In 2007, illicit plantations occupied 99 thousand hectares (UNODC 2008). Deforestation, however, is higher because the establishment of one hectare of coca crop requires to clear four hectares of tropical forests (Nivia 2001; Bernal 2003).[16]

A significant potential for fishing exists in the large areas of marine and continental waters of Colombia but there is no large fishmeal industry in Colombia as there is in Peru. The Atlantic and Pacific Coasts comprise 3 240 kilometers, besides 700 thousand hectares of lakes and 20 thousand kilometers of rivers. Industrial-scale fishing is developed in oceanic waters, above all for export. Shrimp have been grown industrially, affecting mangroves. Continental fishing was an important source of incomes and food security for local populations until the 1980s, when pollution, deforestation, and overexploitation collapsed the activity in the Magdalena River (FAO 2003).

Building materials is in many countries an important item of DE. In Colombia, extraction of building materials increased from 29 to 108 Mt from 1970 to 2007, and industrial minerals exploitation—in part related to the construction activities—from 1.7 to 9.4 Mt. Historically, different governments considered roads and housing policies as fundamental elements to promote economic development because of the links with employment, investment, savings and positive distributional effects. Housing policies, however, have not been able to provide homes for 31% of the families.

There is a close correspondence between patterns of extraction of building materials and economic growth cycles (Giljum et al. 2006; Weisz et al 2006). A higher demand of building materials is promoted because of the infrastructure requirements of growth. Contrarily, investment in physical infrastructure and therefore the use of materials would decline during recession phases. In Colombia, similar trajectories are observed. The deepest fall of the economy in the late 1990s was also a period of depression for the construction sector. Likewise, the economic recovery since 2002 corresponds to the most recent boom in construction activities. In a country like Colombia with low population density, conflicts on the siting of quarries (so widespread in European countries) are not often reported.

[16] In addition, other severe environmental impacts affect tropical forests and populations: pollution due to aerial herbicides fumigations used to eradicate crop, and contamination of water sources and soil by the disposal of chemical wastes from drugs processing.

For over 400 years gold extraction chaotically expanded in Marmato, a traditional small scale mining district of the Andean region in Colombia. Frequent landslides in its high slopes made the area unstable and risky for urban populations. The government solution is to shift the urban settlement to a different location. At the time of writing, the Mining Company of Caldas—subsidiary of the Colombia Goldfields Limited—is planning to undertake large scale open cast mining in the area left without population, with a daily removal of 30 to 60 thousand tons of land and rocks. The affected community—about one thousand inhabitants, however, is complaining (OCMAL 2009). This is just one of the many mining conflicts arising. What is a "preciosity" in the importing countries, such as gold, irrelevant to their metabolic flows, has important socio-environmental impacts in the exporting areas.

It can be concluded that Material Flows indicate several types of pressures on the environment. Often, local inhabitants complain because of the effects of resource extraction. Environmental pressures from the extraction of materials have increased along with several ecological conflicts summarized in table 2. Extraction reaches new "commodity frontiers" controversially demanding materials, including soil, water and other vital resources, besides polluting some ecosystems. Neither economic policies nor technological change avoids the resulting impacts, which disproportionately affect different social groups. This is the ultimate source of protests and resistance expressed through diverse types valuation languages (Martinez-Alier 2002, 2009).

Besides the ecological distribution conflicts discussed in this section—those derived from the extraction of oil, coal, extensive mono-crops, flowers and gold—in table 2 are also described other ecological distribution conflicts. Some variables detailed are: main actors, resources affected per type of commodity, and regions disturbed; linking therefore the study of societal metabolism to the study of political ecology (Gerber et al. 2009). At a larger scale, the conflict we call "ecologically unequal exchange" between primary exporting countries and industrialized countries (Hornborg, 1998) has also been described in this article.

**Table 2: Ecological distribution conflicts in Colombia related to Domestic Extraction**

| Commodity in conflict | Region | Type of commodity | Type of conflict | Main actors | Resources affected |
|---|---|---|---|---|---|
| Oil | Orinoquia Region | Bulk commodity | I | MC, IP | Water, soil, air, biodiversity, forest, traditional knowledge. |
| Coal | Atlantic Coast | Bulk commodity | I | MC, IP, touristic sector | Water, soil, air, human health. |
| Emeralds | Andean Region | Preciosity | N, I | NC, LC | Water, soil, forest. |
| Gold | Andean Region and Pacific Coast | Preciosity | R, I | MC, NC, LC | Water, soil, air, human health, economic options for local communities. |
| Ferronickel | Atlantic Coast | Bulk commodity | I | MC, LC | Water, soil, air, human health. |
| Illicit crops (coca, opium poppy) | Amazonia, Orinoquia, Andean and Pacific Coast | Preciosity | N | NC, LC | Water, soil, air, human health, social relationships |
| Shrimp | Pacific and Atlantic Costs | Preciosity | R, I | NC, LC | Mangroves, water, economic options for local communities |
| Flowers | Andean Region | Preciosity | R, I | MC, NC, LC | Water, soil, food security |
| Sugar cane | Andean Region | Bulk commodity | N, R | NC, LC | Water, soil, human health, food security. |
| Banana | Atlantic Coast | Bulk commodity | N, R | MC, NC, LC | Water, soil, human health. |
| Oil palm | Atlantic and Pacific Coast and Orinoquia | Bulk commodity | N, R | NC, LC | Water, soil, biodiversity, forests, food security. |
| Tropical wood | Amazonia, Orinoquia and Pacific Coast | Bulk commodity | N | MC, NC, IP, LC | Water, soil, biodiversity, forests, cultural values. |

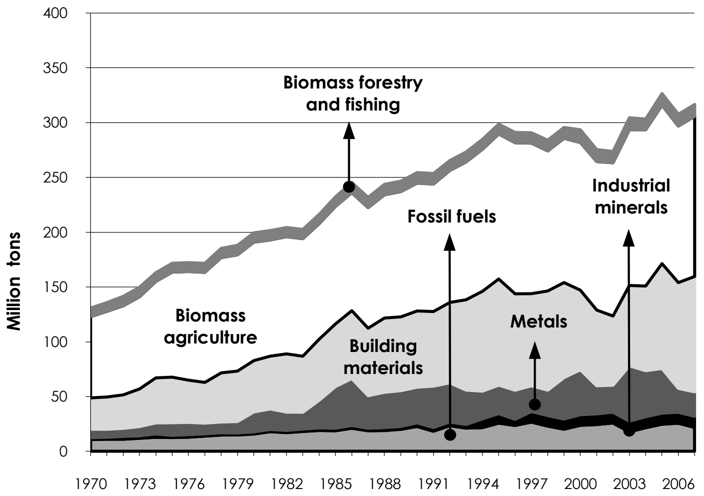
MC: Multinational companies, NC: National Companies, LC: Local communities, IP: Indigenous populations
I: International conflict, N: National conflict, R: Regional conflict
*Source:* Perez-Rincon (2008), Authors' elaboration

### *4.2.2. Domestic Material Consumption*

Productive processes are continuously transforming domestic and foreign inputs into products, a fraction of the products becomes physical exports to the world, and the remaining fraction turns into the DMC. Given that this fraction of materials is employed to further industrial purposes, it constitutes an "apparent consumption", including intermediate inputs. For these reasons, Weisz et al. (2006) identified DMC as an indicator of the "domestic waste potential".

In the Colombian economy DMC has increased from 119 to 278 Mt between 1970 and 2007 as showed in figure 7. It implies an annual growth rate of 2.3%. Like in DE, biomass is the main component of DMC although its share has diminished through the years: from 62% to 53%. Most of these flows comprise biomass for grazing. An important increment, from 20% to 30%, is registered in building materials. Regarding other sorts of resources, no significant changes in terms of structure were recorded but volumes are currently larger.

**Figure 7: Domestic Material Consumption of Colombia (1970-2007).**




*Source:* Authors' estimations

**Table 3: Domestic Material Consumption per decades**
**tons per capita**

| Material Category | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Fossil fuels | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.7 | 0.6 | 0.5 | 0.5 |
| Metal minerals | 0.3 | 0.5 | 0.6 | 1.2 | 0.9 | 0.7 | 1.0 | 0.9 | 0.5 |
| Industrial minerals | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| Building materials | 1.3 | 1.6 | 1.7 | 1.8 | 2.0 | 2.5 | 1.7 | 2.1 | 2.3 |
| Biomass | 3.6 | 4.1 | 4.1 | 3.7 | 3.6 | 3.7 | 3.5 | 3.5 | 3.4 |
| Agriculture | 3.3 | 3.8 | 3.8 | 3.4 | 3.3 | 3.5 | 3.2 | 3.2 | 3.2 |
| Forestry | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 |
| Fishing | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Domestic Material Consumption | 5.8 | 6.8 | 7.0 | 7.4 | 7.3 | 7.8 | 7.0 | 7.3 | 6.9 |
| **Growth rates** | **70-74** | **75-79** | **80-84** | **85-89** | **90-94** | **95-99** | **00-04** | **05-07** | |
| Per capita DMC | 3.2% | 0.0% | -0.1% | -0.5% | 0.9% | -2.0% | -0.7% | -2.8% | |
| DMC | 5.7% | 2.3% | 2.0% | 1.5% | 2.8% | -0.3% | 0.8% | -1.5% | |
| Population | 2.4% | 2.3% | 2.2% | 2.0% | 1.9% | 1.7% | 1.5% | 1.3% | |

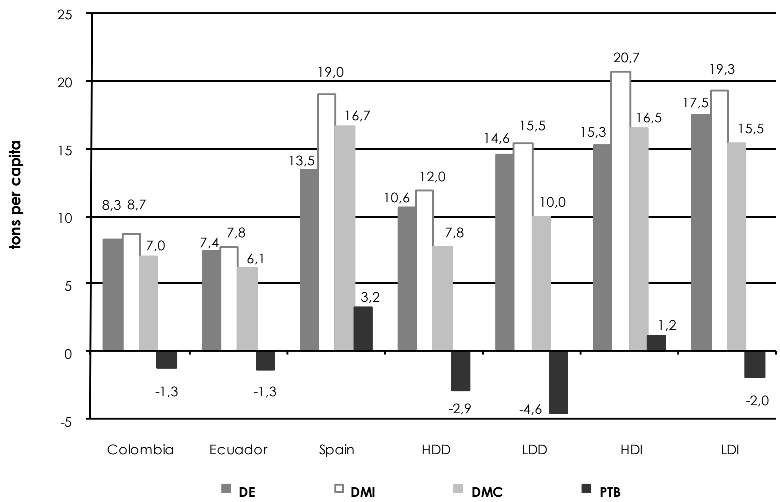
*Sources:* CELADE (2009) and Authors' estimation.

In per capita terms, biomass is also the main component of the DMC. Meanwhile more industrial minerals and building materials are required, biomass consumption is declining. These figures as those of DE show that a transition towards nonrenewable resources is consolidating in the material use patterns. At the same time, population has been growing, but at a decreasing rate. Growth rates of population as well as per capita and aggregate DMC are included in table 3 to compare trends. Per capita DMC increases at a much slower pace (0.5%) than the aggregate DMC (2.4%), than the economy (3.9%) and than population (2%) between 1970 and 2007.

### 4.3. Comparisons of scales and material intensities

The purpose of this section is to compare metabolic profiles of economies with similar and divergent degrees of development, population and territory. In a first comparison is notable that social and economic similar structures get along with the per capita use of material resources. Colombia and Ecuador are small economies, where industrialization and liberalization policies did not consolidate a dynamic path of development. Natural resources are exploited following economic requirements to the detriment of the environmental and cultural wealth. Given this set of structural correspondences, it is not surprising to find analogous metabolic profiles. Per capita volumes of DMC and PTB increased since 1970, although by higher factors in Ecuador.

**Figure 8: Per capita Material Flow Accounts compared (2000).**



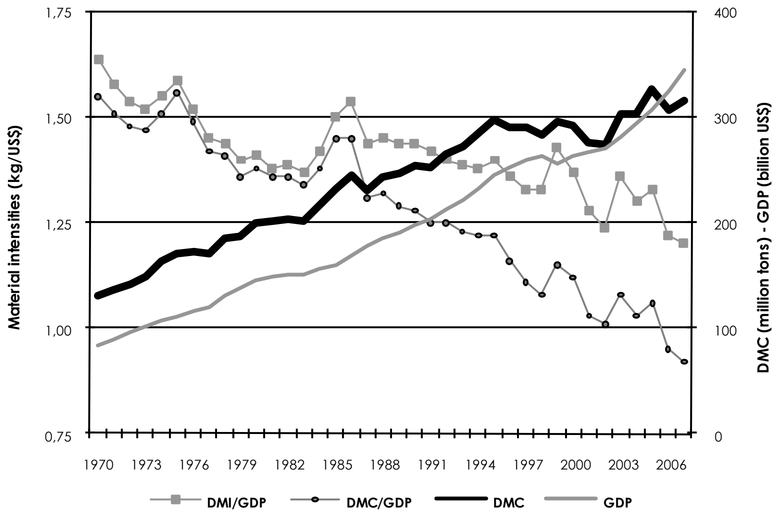

*Notes:* HDD = High density developing; LDD = Low density developing; HDI = High density industrial; LDI = Low density industrial
*Sources:* Krausmann et al. (2008), Sojo et al. (2007), Vallejo (2010), and Authors' estimations

At the other extreme, Spain shows that the level of development determines important disparities in the metabolic profiles. Colombia and Spain had similar populations in

2007 (40 million inhabitants). About 2.4 times more materials per capita are domestically consumed in Spain. This country increased building materials enormously in the boom until 2008. Structurally, just like most European countries, Spain shows a large PTB surplus. The accounts of indirect flows further support arguments of an ecologically unequal exchange between the economic centres and peripheries, and support claims for recognition of the ecological debt from North to South (Machado et al. 2001; Muñoz et al. 2009; Muradian et al. 2002; Pengue 2005).

Finally, MFA have been analyzed by groups of countries clustered according to development status and population density (Krausmann et al. 2008). In figure 8 the metabolic profiles of Colombia and Ecuador are compared to those of both developing and industrialized countries, and both highly-densely and lowly-densely populated countries.

**Figure 9: Material Intensity trends of Colombia (1970-2007).**




*Note:* GDP figures in PPP dollars at 2005 constant prices
*Sources:* Penn World Table 6.3 – Heston et al. (2009) and Authors' estimations

Trends in material intensities of the economies are assessed by the quantity of materials that the economic system uses to produce a single unit of GDP. In Colombia, only 59% of the amount of materials employed (DMC) in 1970 is currently used to produce the economic output. The fraction is 73% in the case of DMI. Differences between intensities with DMI and DMC are explained by export flows.[17] The discrepancy shows an increment in the physical aperture of the economy (Eurostat 2002).

A marked decreasing trend in the material intensity can be seen in figure 9. On average, GDP grew by 3.9%, whereas DMC by 2.4%. Although the natural resources of the country are more and more exploited, and ecological conflicts arise all the time, the "resource curse" is not entirely verified in the sense that economic output is growing faster than the domestic use of material resources. Of course, one could follow the virtuous but unwise path of relative dematerialization until complete resource exhaustion. There are distant signs of this as regards the surface of rainforests in some areas and the oil reserves.

The economy is more efficient because a higher economic value is added for every kilogram of material used. Dematerialization is only true in relative terms because the economy grew by using and depleting its natural endowment. A comparison of the aggregate MFA shows no evidence of absolute dematerialization of the economy. DMI and DMC have changed in line with the economic cycles.

Let us finally look at the Material Flows per hectare. The scale of the physical economy vis à vis its natural environment (Eurostat 2007) is assessed by comparing MFA indicators and the surface area. The amount of materials used per unit of the Colombian land territory increased from 1.2 to 2.9 tons/hectare between 1970 and 2007. Colombian physical economy has expanded regarding its natural environment at a more rapid pace than countries with similar economic and population structures (2.6 versus 1.8 tons/hectare in Colombia and low density developing countries, respectively). Its material use of the space is; however, much lower than the averages of low density industrial countries (4.6), highly populated developing countries (14), and high density developed economies (26).[18]

[17] DMI – DMC = (DE + M) – (DE + M – X) = X
[18] Figures estimated from Kraussman et al. (2008) and WB (2010).

## 5. Conclusions and policy implications

One contribution of this article is the compilation of MFA for the Colombian economy over almost a 40 year period. This constitutes an environmental "satellite" account, valuable to complement the System of National Accounts. This research completes the input side of direct MFA, provides several indicators to analyze the pressure exerted on the natural resource endowment, the environmental conflicts related to such pressures, and identifies some forces driving such patterns. It provides evidences that support a theory of "ecologically unequal exchange". At least at the time of writing, the ECLAC is not yet publishing MFA for the countries that belong to this organization despite the fact that work on material flows is so relevant to debates on international trade and economic policy. Leadership in this work has been taken on by university researchers only: Giljum (2004), Russi et al. (2008), Gonzalez and Schandl (2008), Perez-Rincon (2006), Vallejo (2006a,b). Hence the subtitle of Perez-Rincon's (2006) analysis of Colombian international trade: towards an ecological "Prebisch thesis". Prebisch (1950) was ECLAC's director; he analyzed the deterioration of the terms of trade for primary exports but did not yet study environmental liabilities.

Ecologically unequal exchange, deteriorating terms of trade, absolute increases in material use, reprimarization of the economy, resource extraction conflicts are the most relevant issues discussed in this article on the negative side. On the positive side, relative dematerialization (or increased resource productivity) has made some progress. This metabolic profile provides simple and understandable images of the functioning of the economic system through standardized MFA methods, which are not only interesting for academic purposes but also relevant for the debate on environmental sustainability of the economy. A baseline of biophysical indicators and environmental conflicts will be useful in order to study the environmental and social costs of increasing material use and exports, as also for environmental and economic historians.

These accounts give support to the hypothesis of polarization between extractive and productive economies proposed by Bunker (1985). The global market structure induces an export-led model in extractive economies to exploit an increasing amount of raw material inputs in order to cover metabolic requirements of developed economies (Hornborg 1998), whereas the domestic necessities are frequently relegated. At the same time, the environmental liabilities related to this exploitation patterns are not recognized in market prices. They become visible only through conflicts, and they are evidences of an ecologically unequal exchange. In Colombia as elsewhere, most of the materials required for economic activities are domestically consumed, mainly building materials and agricultural products, but an increasing fraction is exported. This shows a higher dependency on exports, accentuated since the economic policy favoring international trade of the 1990s.

Colombia's material use doubled since 1970, driven largely but not only by population growth. Its composition shows an increasing participation altered by the incremental participation of the nonrenewable sector. According to Krausmann et al. (2009), this is a signal of the transition towards an industrial type social metabolism. However, Colombia has not developed a large and strong industrial sector. Instead of industrializing, the extractive and services activities have been expanded.

An economy traditionally based on agricultural activities requiring the establishment of extensive monocrops and pastures, has definitively caused deforestation at a large scale, the irreversible loss of biodiversity, a disruption of sensitive environments, and a higher intensity in the use of land and agrochemicals. Soil degradation and water pollution are collateral effects of this model, as well as contributing to increased risks to food security because many exportable crops (such as flowers, agrofuels, and others) sacrifice food production. Likewise, open cast mining of coal or other minerals is also a source of hazardous wastes, which threaten human health and the environment.

These forms of disruption of the environment are frequently undertaken in sensitive areas; where threats to indigenous and peasant communities originate environmental conflicts that in the Colombian context are often solved by violence from the military or illegal groups (guerrilla, para-military groups, drug dealers and their armies). These conflicts emerge because of the physical scarcity of some vital resources, and a deteriorated quality in other cases. The increasing depletion of the environmental wealth together with resource extraction conflicts could be interpreted as evidences of a relative "resource curse". That is, not only an economic curse but also a social and political curse. From an economic point of view, economic output has not stagnated during the period. In fact, it has grown faster than the material use. So, there is no "resource curse". However, from a social and political point of view, there is an increasing number of violent ecological distribution conflicts because indigenous and peasant communities see their livelihoods under threat. This is not only a Colombian phenomenon. Conflicts analyzed by political ecology arise everywhere at the "commodity frontiers" in the extraction of oil, mining products, biomass (Martinez-Alier 2002). Distinctive to Colombia is, sadly, the high level of violence.

As in other resource intensive countries from the South, not only domestic efforts to improve the material productivity are required. The total amounts of some ecosystems (forests with their biodiversity, mangroves, coral reefs, *paramos*) must not decrease below agreed limits. Resources such as oil and coal must be preserved for the future, and there are also world-scale arguments to slow down their current rate of extraction because of climate change. In addition, Colombia could explore new policies taxing natural resource exports while asking for compensation for the environmental liabilities, either from its own companies or from companies from the importing industrial countries.

To be more concrete, which instruments of environmental-economic policy could be applied? First, eco-taxes on the depletion of natural resources (sometimes called, "natural capital depletion taxes") have been suggested as a remedy against unsustainable exploitation rates and negative externalities with local or global effects (Daly 2007). Second, Colombia could restrict or even suspend the exploitation of natural resources in some sensitive areas because of social or environmental reasons. For instance, Colombia could promote an OPEC of coal exporters. It could also stop the production of coal in the environmentally most sensitive *paramos* as proposed by environmental NGOs, on the model of the Yasuni ITT proposal in Ecuador (Finer et al. 2009; Larrea and Warnars 2009). Industrial economies' compensations could be assessed as avoided environmental impacts, such as: deforestation, loss of biodiversity, green house gas emissions, pollution, and so on. Finally, in a stage of transition towards a socio metabolic industrial pattern, a more efficient use of materials should be promoted by a reduced quantity per unit of GDP, in total amounts and by unit of land.

**PERFILES SOCIO-METABÓLICOS Y SUS DETERMINANTES. LAS BASES MATERIALES DE TRES ECONOMÍAS ANDINAS ANTE LA ESCALA GLOBAL**

**María Cristina Vallejo**

***Resumen***

*En este artículo se presenta un análisis comparativo de los perfiles socio-metabólicos de tres países andinos: Ecuador, Colombia y Perú, durante el período 1970-2007. Se trata de economías extractivas cuya inserción al comercio mundial implica un intercambio ecológicamente desigual, tanto por la salida neta de recursos materiales que se explotan para cubrir los requerimientos metabólicos de las sociedades industriales, como por las externalidades sociales y ambientales que no se reconocen en los precios de la producción primaria de exportación, y que en algunos casos, como en Ecuador, se traducen en un deterioro de los términos del intercambio. Aunque existen características estructurales similares entre estas economías, sus perfiles metabólicos difieren en términos de escala y estructura, pues la especialización en el sector no renovable minero implica una carga material más pesada para Perú. Mientras Colombia y Ecuador muestran signos claros de desmaterialización relativa, la economía peruana incrementa el uso de materiales por unidad de PIB. En los tres casos, los requerimientos materiales crecen más rápidamente que la población. En la escala global, se demuestra que existen diferencias significativas en los patrones de extracción y consumo de las economías ricas y pobres. Las primeras explotan menos recursos domésticos pero no se registran "efectos de Kuznets" en esta relación, es decir, el aumento de los ingresos per cápita genera incentivos para incrementar el uso de materiales tanto en economías de altos ingresos como en economías de bajos ingresos.*

***Palabras clave:*** Flujos de materiales, economías extractivas, intensidad material, intercambio ecológicamente desigual, perfiles socio-metabólicos.

## 1. Introducción

De acuerdo a Bunker (1985, 2007), existen asimetrías estructurales entre las “economías extractivas” de la periferia y las “economías productivas” del centro. La especialización en la exportación de bienes intensivos en recursos naturales, con escasa generación de valor agregado y mano de obra poco calificada—como el patrón que caracteriza a la mayor parte de países sudamericanos—contribuye al estancamiento económico, a un lento desarrollo y al progresivo deterioro o agotamiento de los recursos naturales. Estas economías funcionan como proveedoras de recursos naturales dentro del comercio mundial, y frecuentemente son reemplazadas conforme determinan las condiciones de precios o la disponibilidad de recursos, situación vulnera su desempeño económico y eventualmente las condena al agotamiento de sus recursos, incluso de sus fuentes renovables.

A fin de evaluar estos aspectos, en este artículo se proponen dos etapas de análisis. En primer lugar, explorar los perfiles metabólicos de tres economías andinas—Ecuador, Colombia y Perú— durante el período comprendido entre 1970 y 2007. Estas economías se pueden catalogar como extractivas por las características de sus perfiles socio-metabólicos. Históricamente se han especializado en la explotación de recursos primarios para el consumo local o para la exportación, pero difieren en términos de escala y estructura metabólica. Para Colombia y Ecuador la biomasa es la base de su estructura, mientras que la especialización en el sector no renovable minero implica una carga material más pesada para Perú. En segundo lugar, se propone estudiar los determinantes del uso de materiales contextualizando los casos andinos en la escala global a fin de contribuir a la discusión sobre un intercambio ecológicamente desigual entre economías con diferentes características estructurales.

A través de la curva ambiental de Kuznets se ha planteado que las economías de altos ingresos podrían destinar recursos a la protección ambiental y por lo tanto, reducir las presiones que ejercen en el ambiente. Uno de los argumentos que darían soporte a estas ideas sería la desmaterialización relativa que caracteriza a estas economías, debido al uso de una menor cantidad de materiales por unidad de producción (Cleveland y Ruth

1998). En tal sentido, las asimetrías estructurales en el uso de materiales a escala global podrían ser determinadas tanto por la condición de economías extractivas, como por la disponibilidad de ingresos para destinar a la protección ambiental. En este estudio se plantea que las economías de altos ingresos en efecto estarían explotando menos recursos domésticos que las economías de escasos ingresos, pero sustentan su funcionamiento metabólico en el uso de materiales importados, trasladando presiones ambientales fuera de sus fronteras. Con este propósito, se exploran los determinantes del uso de materiales para un grupo de economías con representatividad en la escala global durante el año 2000, considerando diferentes niveles en el uso de materiales.[19]

Los flujos e indicadores que se derivan de la contabilidad de los flujos de materiales, son herramientas apropiadas para analizar estos aspectos, pues se cuantifica el sustento material de las economías a través de indicadores físicos, que a su vez miden las presiones ambientales que se generan por la explotación de recursos naturales a lo largo de la cadena productiva. El fundamento de este esquema analítico es el concepto de "metabolismo de las sociedades" (Ayres y Simonis 1994; Fischer-Kowalski 1998; Fischer-Kowalski y Haberl 1993, 1997), de acuerdo al que, tal como un organismo vivo necesita alimentarse, procesar recursos y luego desecharlos para su funcionamiento metabólico, las economías funcionan de manera similar, extrayendo de la naturaleza materia y energía de alta calidad (baja entropía), a fin de procesarlos y generar bienes y servicios, que luego de consumirse, reciclarse o acumularse como stocks, son devueltos a la naturaleza en la forma de residuos de baja calidad (o alta entropía).

Este artículo está organizado en seis secciones. Después de esta introducción se presenta una breve explicación de los métodos, las definiciones y las fuentes de información empleadas. En la tercera sección se exponen algunos rasgos históricos y características estructurales que describen a las economías andinas en la escala global. Esta sección es una introducción que permite comprender mejor los perfiles de uso doméstico de recursos materiales así como los flujos de comercio externo de los tres países andinos

[19] Esta distinción se hace necesaria porque varias investigaciones sobre los perfiles socio-metabólicos de Europa demuestran que los niveles per cápita de uso de materiales y su composición pueden diferir mucho entre economías con un nivel similar de ingreso per cápita (Bringezu et al. 2004; ETC-WMF 2003; Eurostat 2002; Weisz et al. 2006).

que se exponen en la cuarta sección en el contexto de la escala global. La quinta sección presenta una estimación econométrica de los determinantes del uso de materiales, y las diferencias que se pueden registrar entre países de altos y bajos ingresos, así como entre economías extractivas y no extractivas. Finalmente, en la última sección se discuten las principales conclusiones del documento.

## 2. Fuentes de información y métodos

Para el análisis de las economías andinas se emplea información recientemente estimada por Vallejo et al. (2010) sobre Colombia, y Vallejo (2010) sobre Ecuador. En el caso de Perú se revisan las cifras presentadas por Russi et al. (2008) y Silva (2007), corrigiendo y actualizando las estimaciones de los diferentes flujos. En particular, se expande la base de datos con cifras que van desde 1970 hasta 2007,[20] y se aplica la estimación recientemente planteada por Krausmann et al. (2009) para el cálculo de los flujos de extracción doméstica de materiales de construcción. Se emplean datos de producción de cemento del USBM (2009), de producción de bitumen de la UNSD (2009b) y de construcción de caminos asfaltados de la IRF (2009).[21]

En el caso de los minerales metálicos y no metálicos de Perú también se considera una fuente de información distinta a la reportada por los estudios anteriores. Ahora se utilizan los anuarios mineros del USBM, que suponen dos ventajas. Por un lado, contienen datos para todo el período de análisis requerido, y por otro lado, además de reportar los materiales contabilizados en los estudios anteriores—esto es, antimonio, cobre, estaño, hierro, molibdeno, oro, plata, plomo y zinc—además reportan datos sobre la extracción de cadmio, arsénico, bismuto, cromo, indio, mercurio, selenio, telurio, y tungsteno, que también se extraen en ese país. Las principales definiciones de flujos de materiales empleadas, así como las fuentes de datos y factores de conversión aplicados en esta actualización de las cifras de Perú se detallan en la tabla 1.

[20] Los datos presentados en Russi et al. (2008) sólo abarcan el período comprendido entre 1980 y 2000.
[21] Las cifras de materiales de la construcción que se reportan en Russi et al. (2008) se basan es estadísticas de la población, asumiendo 3 toneladas per cápita para economías de bajos ingresos, como es el caso de Perú. El problema de este método es que estos datos no reflejan importantes ciclos económicos que tienen impactos en el desempeño del sector de la construcción.

**Tabla 1: Definiciones, fuentes de información y factores de conversión.**

| *Categoría de flujo o indicador* | *Descripción* | *Fuentes de datos* | *Factores de conversión aplicados* |
|---|---|---|---|
| | ***Flujos de materiales*** | | |
| Extracción doméstica | Es la extracción o movimiento deliberado recursos materiales por parte de los seres humanos o a través de medios tecnológicamente controlados por éstos (es decir, aquellos que involucran trabajo humano). | Ver las categorías de materiales. | |
| Importaciones y exportaciones físicas | Productos importados y exportados, clasificados conforme la clasificación ISIC Rev.2 de las Naciones Unidas por su principal componente material. | UNSD (2009) | Información se reporta en kg (1 ton = 1000 kg). |
| | ***Indicadores de flujos de materiales*** | | |
| Insumos directos de materiales (IDM) | Son los insumos domésticos y externos de materiales que permiten el desarrollo de las actividades económicas. Extracción doméstica utilizada + importaciones físicas. | | |
| Consumo doméstico de materiales (CDM) | Es la proporción de todos los materiales que permanece en el sistema económico hasta ser desechado al ambiente. Extracción doméstica utilizada + importaciones físicas – exportaciones físicas. | | |
| Balance comercial físico (BCF) | Es la salida (entrada) neta de materiales desde (hacia) el medio ambiente doméstico hacia (desde) otras economías del mundo. Importaciones físicas – exportaciones físicas. | | |
| | ***Categorías de materiales*** | | |
| Biomasa | Materiales biológicos que son movilizados por los seres humanos o por el ganado durante un año | FAO (2009). | Ver las sub-categorías. |
| Cultivos primarios | Comprende: cereales, raíces y tubérculos, legumbres, cultivos oleaginosos, verduras, frutas, fibras, y otros cultivos primarios (estimulantes, caña de azúcar, especias). | FAO (2009). | Información se reporta en toneladas |
| Biomasa del pastoreo de ganado. | Es la demanda total por pastos de todos los tipos de ganado expresados en unidades ganaderas (UG). | FAO (2009). | 7 kg de materia seca al día por UG. |
| Forraje | Residuos de los cultivos de caña de azúcar (bagazo) y cereales que se emplean como forraje. | FAO (2009); OLADE (2007). | Para los cereales se asume el 50% del peso de los cultivos. |
| Biomasa forestal | Madera cosechada de bosques, plantaciones, o tierras agrícolas: combustible de leña, madera aserrada, y madera apenas preparada. | FAO (2009). | Dependiendo de la especie (conífera o no conífera), y el tipo de madera: entre 250 y 950 kg/m$^3$ de materia seca. |
| Biomasa de la pesca | Capturas de peces, crustáceos, moluscos, e invertebrados acuáticos. | FAO (2009). | Información se reporta en toneladas |
| Minerales | Minerales metálicos y minerales industriales medidos en su contenido metálico bruto. | USBM (2009). | Contenido metálico de: 0,0001% en oro, 0.03% en plata, 1% en cobre, 10% en plomo, y 12.2% en zinc. |
| Materiales de construcción | Arena y grava empleadas para la producción de concreto y asfalto. Además, otros materiales de construcción que se emplean. | IRF (2009); UNSD (2009); USBM (2009). | Razón de cemento a concreto: 1 a 6,5 ton. Razón de bitumen a asfalto: 1 a 20 ton. |
| Combustibles fósiles | Producción de combustibles fósiles. | OLADE (2007) comparada con OPEC (2007). | 6,88 barriles/ton de petróleo, 0,8 kg/m$^3$ de gas natural. |

*Fuentes:* Eurostat (2001, 2007), elaboración propia

En esta comparación de perfiles socio-metabólicos, son fuentes importantes los estudios existentes que refieren a economías en desarrollo, es el caso de González y Schandl (2008), Eisenmenger et al. (2007), Muñoz et al. (2009), Pérez-Rincón (2006, 2008), Russi et al. (2008), Vallejo (2006a, 2006b, 2010), Vallejo et al. (2010).

En la segunda parte del análisis empírico que se desarrolla en este trabajo se consideran las cifras de las economías andinas analizadas en la primera parte del documento, las cuales complementan los datos sobre flujos de materiales y energía construidos por Krausmann et al. (2008) para el año 2000. Estos autores presentan información para 175 países del mundo. No obstante, en este artículo se realizan estimaciones sobre la base de estadísticas compiladas para 151 países de este grupo, considerando aquellos casos que disponen de datos relativos a los determinantes del uso de materiales que se analizan, cuyas fuentes son el Banco Mundial (WB, 2010), la FAO (2010) y la UNSD (2010).

## 3. Características estructurales de tres países andinos y la escala global

Existen rasgos similares en la historia económica de la región andina que pueden explicar patrones afines en estas economías extractivas. Al menos cuatro fases de desarrollo se distinguen en el contexto latinoamericano desde 1970:

a. El fin del modelo de industrialización por sustitución de importaciones (ISI) en los setenta.
b. La fase de estancamiento económico en la denominada "década perdida" de los años ochenta.
c. La liberalización económica de los flujos de comercio y de capital en los años noventa, que tuvo lugar a través de la eliminación parcial o total de barreras comerciales y la privatización de algunos servicios o bienes públicos.
d. Una etapa de recuperación económica que duró hasta el año 2008, la misma que tuvo lugar con el incremento de precios de diversos bienes primarios, tras la crisis económica que se registró a fines de los años noventa.

Una revisión de las características estructurales de estas tres economías andinas se presenta en la tabla 2, en un esquema comparativo con la escala global para el año 2000. Se comparan estos países con los promedios para algunos países agrupados de acuerdo a su condición de ingresos per cápita o la calidad de economías extractivas o no extractivas. Aunque el Ecuador es el país más pequeño en términos de territorio, población y PIB, su crecimiento económico es el más dinámico. Mientras el PIB peruano creció a una tasa acumulada anual de 2,7%. Colombia y Ecuador crecen a tasas similares de 3,9% y 4,2% entre 1970 y 2007.

En términos de espacio, Colombia y Perú son parecidas: 1,1 y 1,3 millones de $km^2$. Por otro lado, el Ecuador es cuatro veces más pequeño, y se halla más densamente poblado que los otros dos países. Aunque las densidades poblacionales de estas economías andinas se han duplicado desde 1970 hasta 2007, su nivel todavía está lejos del promedio en la EU-15, por ejemplo (116,2 habitantes por $km^2$ en 2007). En los territorios andinos se alberga una amplia variedad de ecosistemas, que tienen un importante potencial para la explotación de recursos en bosques tropicales, agro-ecosistemas, pastizales, manglares, arrecifes de coral, páramos, y aguas continentales o marinas.

Para ubicar la posición de estas economías andinas en la escala global se emplea información de un grupo de 151 países. Estos indicadores que se detallan en la tabla 2, constituyen los factores determinantes del uso de recursos materiales que se analizan en la quinta sección. Estas variables explicativas han sido seleccionadas en base a la literatura reciente sobre determinantes del uso de materiales (Krausmann et al. 2008, Weisz et al. 2006). Se distinguen cuatro grupos de países. Economías de altos ingresos—cuyo PIB per cápita se halla por encima del promedio (US$ 10 mil dólares PPP), economías de bajos ingresos, economías extractivas,[22] economías no extractivas.

El 31% de los países analizados son economías de altos ingresos, el 26% de países se clasifican como densamente poblados, y el 41% como extractivas. Las tres economías andinas se hallan en la categoría de economías extractivas con bajos ingresos y baja densidad poblacional. La población agrícola en las economías de altos ingresos se

[22] Varios autores definen a las economías extractivas como aquellas que se especializan en la extracción de recursos naturales que se destinan principalmente a la exportación pero relegan el consumo doméstico (Bunker 1985; Eisenmenger y Giljum 2006). Sobre la base de esta definición, se clasifica la información de Krausmann et al. (2008), identificando como economías extractivas a aquellas que son exportadoras netas de materiales y/o aquellas que exportan una proporción significativa del total de materiales disponibles para el uso económico (X/IDM), este promedio es de 14% en la escala mundial. Aunque esta clasificación no está libre de limitaciones, se trata de una buena aproximación considerando la información que se halla disponible.

calcula en 8% del total, y en economías de bajos ingresos en 45%. En Colombia, Ecuador y Perú esta fracción es similar al promedio de las economías extractivas, esto es, alrededor de 25%. En promedio, cada habitante de las economías de bajos ingresos tendría acceso a alrededor de 5,6 hectáreas de territorio, y menos de 2,2 hectáreas de tierra agrícola. Las economías extractivas generan mayores ingresos por la exportación de bienes y servicios (52% del PIB) que las economías no extractivas (40%). Ecuador se halla por encima del promedio de la región andina analizada (40%), pues Colombia y Perú obtienen aproximadamente 17% del PIB como ingresos por la exportación. Finalmente, en términos de desarrollo humano, las tres economías andinas se hallan por encima del promedio de las economías de bajos ingresos, muy cercanas a la posición de las economías extractivas.

**Tabla 2: Estadísticas descriptivas de los determinantes del uso de materiales (2000)**

| *Variables* | *Unidad* | *Total* | *Altos ingresos* | *Bajos ingresos* | *Extrac.* | *No extract.* | *Col* | *Ecu* | *Per* |
|---|---|---|---|---|---|---|---|---|---|
| ED | ton/habit | 12,59 | 22,92 | 7,93 | 18,83 | 8,25 | 8,25 | 7,22 | 13,83 |
| DCM | ton/habit | 11,10 | 18,83 | 7,60 | 13,73 | 9,26 | 6,97 | 5,95 | 13,78 |
| Exportaciones de materiales | ton/habit | 3,57 | 9,36 | 0,96 | 7,96 | 0,51 | 1,59 | 1,58 | 0,53 |
| Importaciones de materiales | ton/habit | 2,07 | 5,26 | 0,63 | 2,86 | 1,53 | 0,31 | 0,31 | 0,47 |
| Países de alta densidad poblacional | % | 26 | 43 | 19 | 23 | 29 | 0 | 0 | 0 |
| Economías de altos ingresos | % | 31 | 100 | 0 | 44 | 22 | 0 | 0 | 0 |
| Economías extractivas | % | 41 | 57 | 34 | 100 | 0 | 100 | 100 | 100 |
| PIB | US$ PPP/habit | 9.928 | 23.294 | 3.887 | 13.432 | 7.487 | 6.607 | 4.872 | 4.981 |
| Exportaciones | US$ PPP/habit | 4.603 | 11.375 | 1.542 | 6.964 | 2.958 | 1.123 | 1.803 | 797 |
| Importaciones | US$ PPP/habit | 4.312 | 10.000 | 1.741 | 5.703 | 3.343 | 1.255 | 1.510 | 897 |
| Deuda externa | US$ PPP/habit | 4.233 | 8.576 | 2.270 | 5.315 | 3.479 | 2.384 | 4.144 | 2.677 |
| Índice de desarrollo humano | | 0,70 | 0,89 | 0,61 | 0,76 | 0,66 | 0,77 | 0,76 | 0,77 |
| Territorio disponible | ha/habit | 5,50 | 5,28 | 5,60 | 6,73 | 4,65 | 2,71 | 2,24 | 5,01 |
| Tierra agrícola | ha/habit | 2,01 | 1,60 | 2,19 | 1,78 | 2,16 | 1,08 | 0,65 | 0,85 |
| Densidad poblacional | habit/km$^2$ | 104,82 | 154,33 | 82,44 | 78,69 | 123,01 | 34,87 | 43,89 | 20,30 |
| Población total | habitantes | 38,00 | 24,20 | 44,20 | 25,10 | 46,90 | 42,10 | 12,60 | 25,70 |
| Población urbana (%) | % | 53 | 74 | 44 | 62 | 47 | 72 | 60 | 71 |
| Población agrícola (%) | % | 34 | 8 | 45 | 24 | 41 | 20 | 26 | 28 |
| Energía agrícola per cápita | GJ | 38,31 | 51,40 | 32,39 | 42,38 | 35,47 | 47,49 | 39,61 | 34,14 |
| Energía de madera per cápita | GJ | 9,80 | 12,94 | 8,38 | 14,18 | 6,75 | 3,65 | 5,62 | 4,53 |
| Energía de carbón mineral per cápita | GJ | 9,31 | 21,12 | 3,97 | 14,70 | 5,55 | 25,59 | 0,00 | 0,02 |
| Energía de petróleo per cápita | GJ | 94,73 | 255,40 | 22,12 | 226,48 | 2,95 | 37,76 | 73,68 | 8,95 |
| Energía de gas per cápita | GJ | 34,29 | 97,42 | 5,76 | 79,98 | 2,47 | 6,03 | 1,04 | 0,81 |
| Hidroenergía per cápita | GJ | 12,13 | 32,53 | 2,92 | 13,92 | 10,89 | 2,89 | 2,28 | 2,48 |
| Número de observaciones | | 151 | 47 | 104 | 62 | 89 | | | |

Elaboración propia

Estas son condiciones estructurales que caracterizan a las economías andinas en el contexto mundial. Muchos de estos factores influyen en los patrones de extracción, consumo, y exportación de materiales. La dimensión biofísica de estas economías puede evaluarse en la escala global para identificar los determinantes de los patrones de uso de materiales así como las diferencias entre economías.

## 4. Las bases materiales de las economías andinas

Los indicadores físicos constituyen herramientas importantes para medir la sostenibilidad de las economías, pues permiten identificar las presiones que la actividad humana ejerce en el ambiente, e incluso confieren señales indirectas de impactos ambientales (Van der Voet et al. 2008; Krausmann et al. 2009) a lo largo de la cadena de las actividades extractivas y productivas, esto es, desde el procesamiento, transporte, intercambio y consumo, hasta la disposición de los residuos en la naturaleza.

En esta sección se distinguen cinco categorías de materiales: biomasa, combustibles fósiles, minerales metálicos, minerales industriales y materiales de construcción, tanto en los flujos de extracción doméstica (ED), importación (M) y exportación (X), así como en los indicadores de consumo doméstico (CDM), insumos directos de materiales disponibles (IDM) y el balance comercial físico (BCF). Tal como sucede en la escala global (Krausmann et al. 2009), las economías andinas muestran cambios importantes en sus bases materiales. La biomasa continúa siendo el principal material que se extrae y se consume internamente, pero el uso de fuentes no renovables de materia está creciendo a un ritmo cada vez más acelerado. En las exportaciones colombianas predomina el tonelaje de carbón, en Ecuador el petróleo, y en Perú la minería.

Un preámbulo necesario en este análisis es la identificación de los diferentes roles que los flujos de materiales analizados cumplen en el funcionamiento metabólico de las economías. Por un lado, aunque la tendencia en el uso de biomasa es decreciente, esta materia prima constituye un flujo metabólico fundamental en el sistema socio-económico, pues es irremplazable como fuente de nutrientes para la población (Weisz et al. 2006). Por otro lado, los combustibles fósiles constituyen fuentes esenciales de energía para el funcionamiento metabólico de las economías industriales. Los materiales de construcción cumplen una función importante en el desarrollo económico y calidad de vida de la población. Finalmente, en el otro extremo se hallan las así llamadas “preciosidades” por su alto valor monetario por unidad de peso (Hornborg et al. 2007), cuya extracción deriva gran cantidad de materiales de desecho, muchos de ellos altamente contaminantes y seriamente conflictivos, que resultan ser irrelevantes en el funcionamiento metabólico de las economías que los consumen.

### 4.1 Perfiles metabólicos en el uso de materiales

En el caso del Ecuador, durante todo el período analizado, la biomasa ha constituido la principal fuente de materiales. En 1970, la biomasa que se extrajo en actividades agrícolas y pecuarias constituyó un 70% de la ED total del país. Sin embargo, el inicio de la explotación petrolera introdujo cambios significativos en su estructura económica y material. En 1973, los combustibles fósiles—sin incluir carbón mineral que no se explota—se contabilizaron en 30% de la ED, mientras que la biomasa agrícola disminuyó hasta un 48%. Para el año 2007, la biomasa ha perdido participación y se contabiliza como 31% de la ED. Por otro lado, los materiales de construcción y los combustibles fósiles han ganado peso progresivamente, incrementándose desde 14% en 1970 hasta 30% en 2007 para el caso de los materiales de construcción, y desde 1% hasta 24% en el segundo caso.

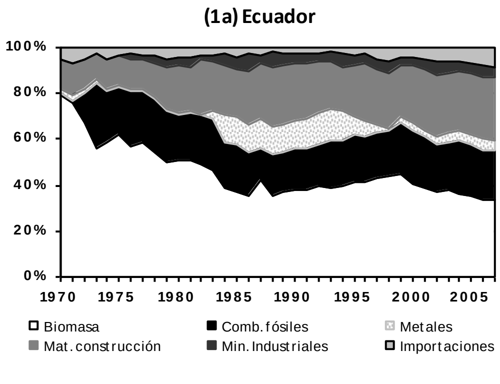
En Colombia se registra una transición similar, desde el sector renovable hacia el no renovable, aunque en este caso ha sido un cambio menos severo. Los cultivos primarios se han mantenido en 16% de la ED a lo largo de 37 años, pero la biomasa que se deriva del pastoreo y forraje para ganado ha disminuido desde 39% hasta 21% durante este período. Aunque también en este caso la biomasa sigue siendo el principal componente de la ED, se registra también un crecimiento relativo importante en el sector no renovable de esta economía, desde 39% en 1970 hasta 61% en 2007, siendo el crecimiento de la extracción de carbón mineral uno de los factores determinantes.

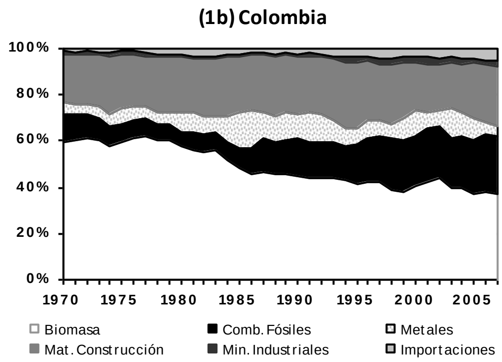
La transformación económica y material de la economía peruana ha sido aún más dramática. La explotación de recursos no renovables pasó del 46% al 83% durante el período analizado. En este caso es la extracción de minerales metálicos la principal explicación de estos cambios, pues la fracción de estos materiales en la ED total aumentó desde 29% en 1970 hasta 66% en 2007, mientras que los combustibles fósiles y los materiales de construcción casi no muestran cambios.

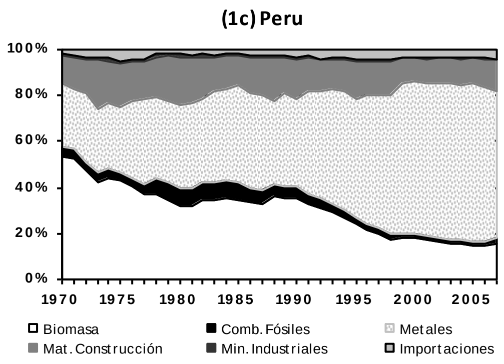
Para el año 2000, se registró un amplio margen de variación en los niveles de ED a escala global. En las economías de altos ingresos se extrae un mínimo de 9 y un máximo de 67 toneladas per cápita, en países en desarrollo se registra un margen aún más amplio que va desde 2 a 27 toneladas por habitante. Los materiales de construcción son el principal componente de la ED en las economías de altos ingresos que se analizan, éstos representan en promedio el 44%, un segundo componente es la biomasa (27%), luego los combustibles fósiles (22%) y el resto son metales. Por otro lado, en las economías de bajos ingresos, los materiales de construcción representan alrededor del 45% de la ED, la biomasa 34%, los combustibles fósiles 15% y el resto son metales.

**Gráfico 1:**

**IDM por categorías de materiales en las economías andinas (1970-2007).**



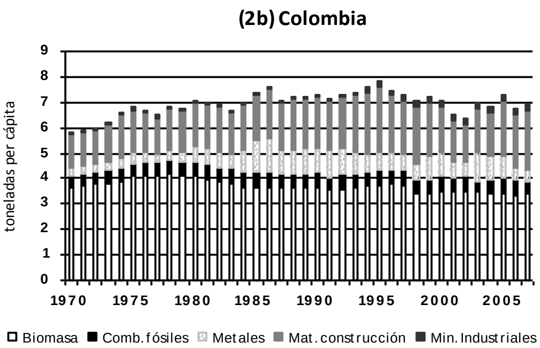

*Fuentes:* Vallejo (2010), Vallejo et al. (2010), estimaciones propias.

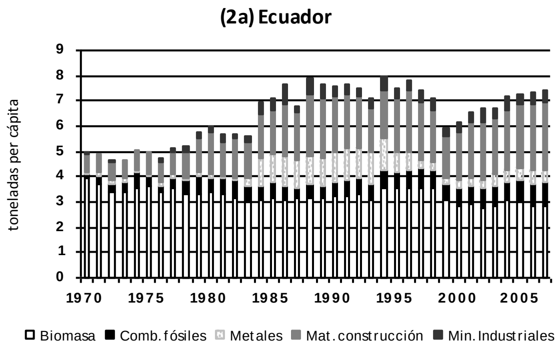
El segundo componente del total de insumos materiales disponibles para la economía (IDM) son las importaciones de materiales. En las tres economías andinas, las importaciones representan una fracción menor en los IDM, aunque estos flujos suelen variar inestablemente. En el caso de Ecuador, se han incrementado del 5% al 9% en el transcurso de 37 años, en Colombia del 1% al 5%, y en Perú del 2% al 4%. En los gráficos 1a, 1b y 1c se presenta el IDM de Ecuador, Colombia y Perú, respectivamente. En estos gráficos se distinguen los distintos componentes de la ED y la proporción de importaciones.

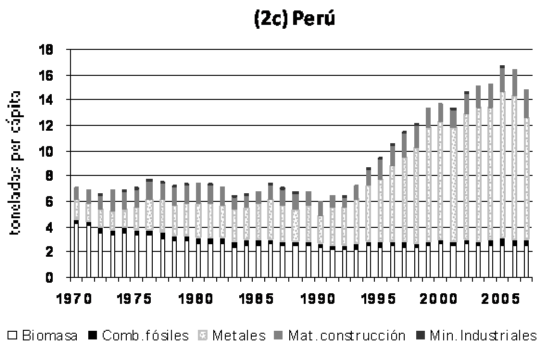
Una vez que tienen lugar los procesos productivos, los insumos materiales se transforman en el sistema económico. Una fracción de éstos se consume internamente, otra fracción se exporta y también se generan residuos materiales que retornan al ambiente. Los flujos que se consumen en las tres economías andinas se resumen en los gráficos 2a, 2b, y 2c en términos per cápita.

**Gráfico 2:**

**CDM per cápita por categorías de materiales en las economías andinas (1970-2007).**



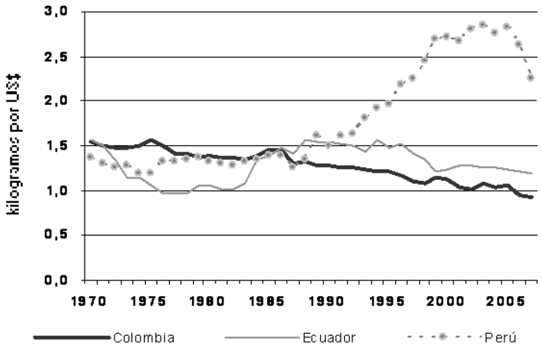




*Fuentes:* Vallejo (2010), Vallejo et al. (2010), estimaciones propias.

El consumo por habitante en Ecuador ha crecido de 5 a 7 toneladas hasta 2007, que se componen fundamentalmente de biomasa y materiales de construcción, pues la mayor parte del petróleo crudo que se extrae se exporta. La población se ha duplicado en este período, creciendo cada vez más lentamente a una tasa anual de 2,3%, mientras el CDM agregado se ha incrementado a razón de 3,4% al año y el PIB en 4,2%. Aunque el uso de materiales crece más rápidamente que la población, al mismo tiempo la eficiencia material de la economía se ha incrementado pues se utilizan menos recursos materiales por cada dólar de PIB que se produce, o visto inversamente, ha disminuido la intensidad material de la economía aunque en ciertos períodos se registraron retrocesos en la evolución de la eficiencia material—por ejemplo, en la segunda mitad de la década de los ochenta, cuando la década perdida se tradujo en estancamiento económico.

Un perfil metabólico similar caracteriza a Colombia, en esta economía se consumían casi 6 toneladas por habitante en 1970, actualmente se consumen 7. En este caso, sin embargo, el uso de biomasa ha cedido menos espacio a los materiales de construcción. Tal como en Ecuador, la tasa de crecimiento de la población va disminuyendo paulatinamente en Colombia y se registra una tasa anual de 2% a lo largo del período. El uso de materiales, sin embargo, crece más rápidamente que la población—a una tasa de 2,4%—y más lentamente que el PIB—al 3,9% anual. En Colombia existe una clara tendencia decreciente en la intensidad material.

**Gráfico 3**
**Intensidad material**
**de las economías andinas (1970-2007).**



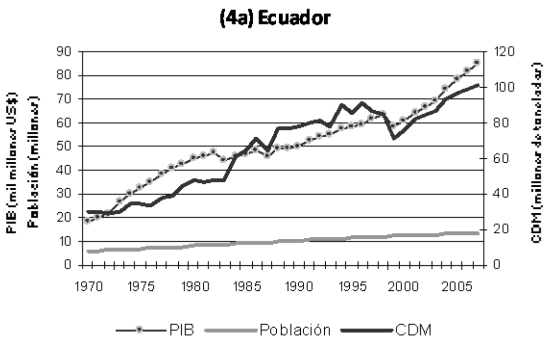

Fuentes: Vallejo (2010), Vallejo et al. (2010),
estimaciones propias.

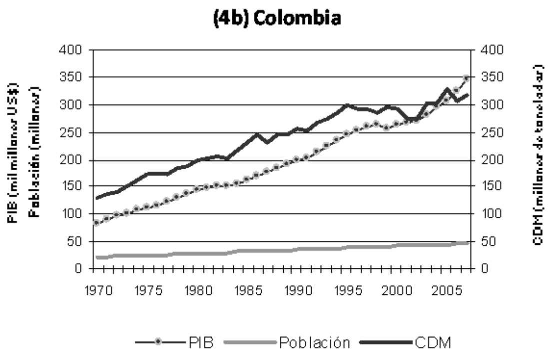
Finalmente, en Perú la escala de uso de materiales era bastante similar a la ecuatoriana y colombiana en 1970, pero la expansión de la minería metálica ha duplicado el consumo doméstico por habitante hasta el año 2007, pasando de 7 a 15 toneladas. Alrededor de 10 toneladas son minerales metálicos, que al registrarse en su contenido bruto incluyen materiales que forman parte de la extracción doméstica pero que tras el proceso de concentración de minerales terminan como desechos domésticos de la industria minera

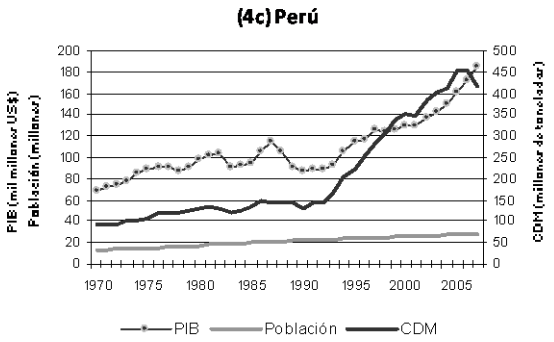
(Giljum 2004; Russi et al. 2008). La intensidad material de esta economía, a diferencia de los perfiles registrados en Ecuador y Colombia, se ha incrementado hasta el año 2002, esto significa que se cada vez se usan más materiales por cada dólar de la producción. En el último quinquenio de análisis se observan ciertos avances en términos de eficiencia material. No obstante, el uso de recursos crece más rápido que la población y el PIB: las tasas de crecimiento anual son 4,1%, 2% y 2,7%, respectivamente. En el gráfico 3 se presentan las intensidades materiales de estas tres economías andinas.

**Gráfico 4:**

**Intensidad material absoluta de las economías andinas (1970-2007).**




Fuentes: Vallejo (2010), Vallejo et al. (2010), estimaciones propias.

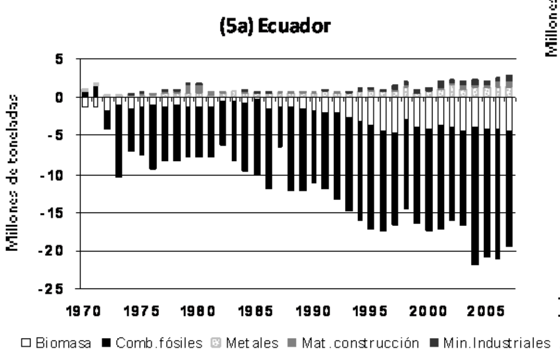
Para el año 2000, cada habitante de las economías ricas que se analizan consumió en promedio 2,5 veces más materiales que cada habitante de las economías de bajos ingresos. Mientras que las economías extractivas consumen en promedio 1,5 veces más que las economías no extractivas. Las tendencias de los flujos de materiales analizados en esta sección, muestran que el uso de materiales en términos absolutos se incrementa en las tres economías andinas, en un patrón que evoluciona en línea con los ciclos económicos. Otros análisis comparativos también demuestran que mientras una economía crece consume una mayor cantidad de materiales (Weisz et al. 2006). A fin de analizar estos aspectos, en los gráficos 4a, 4b y 4c se muestra la evolución de los flujos agregados de CMD en Ecuador, Colombia y Perú, junto con el PIB y la población.

### *4.2 Balances materiales en el comercio exterior e intercambio ecológicamente desigual*

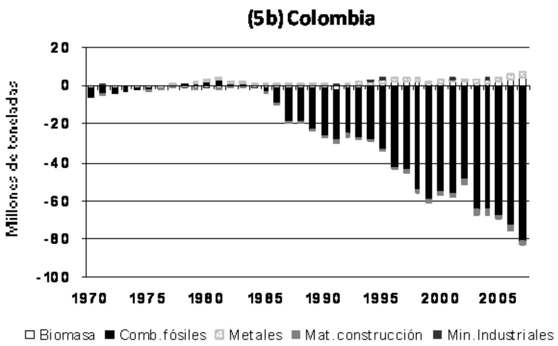
Los balances comerciales físicos de los países de la región andina muestran en el agregado saldos negativos por la salida neta de materiales domésticos hacia el exterior, aunque en algunas categorías de materiales existen saldos positivos. En el caso ecuatoriano, la mayor parte de los materiales que se exportan se componen de biomasa y combustibles fósiles. En el caso de Colombia es notable el peso del carbón mineral en su desbalance material, así como en Perú se distingue el efecto de los minerales metálicos que se exportan. Estos saldos negativos en el intercambio internacional se expanden a partir de la década de los años noventa, coincidiendo dicha evolución con la etapa de liberalización comercial que favoreció la importación pero principalmente la exportación de materiales. La composición de los BCF y su evolución se pueden analizar en el gráfico 5.

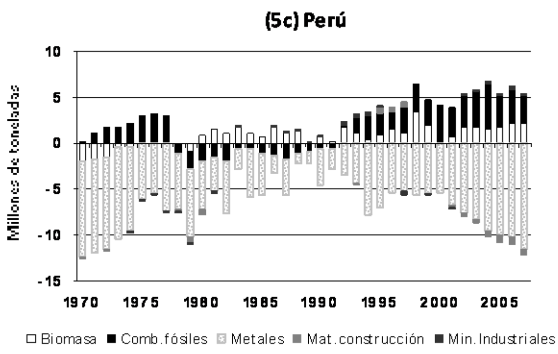
**Gráfico 5:**

**BCF por categorías de materiales en las economías andinas (1970-2007).**




*Fuentes:* Vallejo (2010), Vallejo et al. (2010), estimaciones propias.

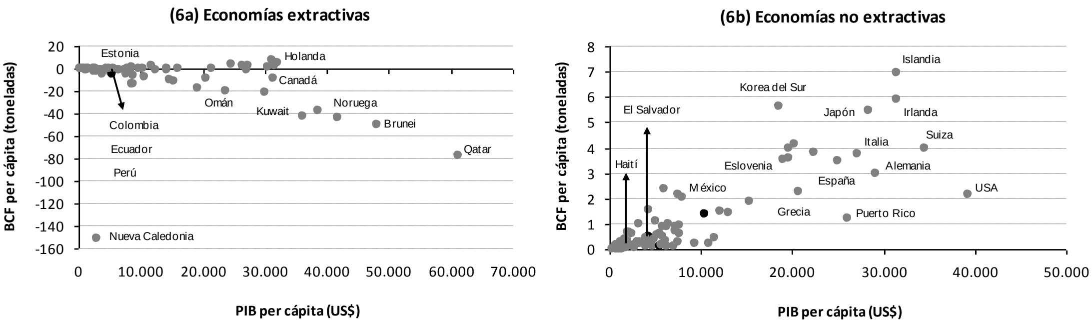



En el gráfico 6 se comparan los BCF per cápita a escala mundial por niveles de ingreso per cápita. Se distinguen dos grupos de países para este análisis, "economías extractivas" y "no extractivas". En primer lugar, se identifican economías extractivas tanto con altos como con bajos ingresos per cápita. Canadá, Noruega o Qatar, por ejemplo, son economías con altos ingresos y un BCF negativo debido a la exportación de combustibles fósiles. Las economías andinas se hallan en el otro extremo de ingresos y sus BCF son negativos. Un segundo aspecto a destacar es que existe un amplio margen de variación en los BCF de las economías extractivas: entre 7,5 y -151,1 toneladas per cápita. Por otro lado, entre las economías no extractivas el saldo del balance físico per cápita varía entre 0,01 y 6,9 toneladas.

**Gráfico 6:**

**BCF en la escala global. Economías extractivas versus no extractivas.**




Fuentes: Krausmann et al. (2008), estimaciones propias.

Estas tendencias muestran un intercambio ecológicamente desigual entre economías con diferentes características estructurales. Mientras las economías extractivas explotan sus bases materiales para satisfacer la creciente demanda externa de recursos básicos, las economías de altos ingresos sustentan una mayor proporción de su funcionamiento metabólico en el uso de recursos importados. En efecto, la proporción de importaciones en los IDM de las economías ricas es en promedio 19%, mientras que en economías con bajos ingresos esta proporción es en promedio sólo 7%.

La evolución de los términos del intercambio en la región también contribuye a la discusión sobre el intercambio ecológicamente desigual, aunque existen tendencias diversas en las economías andinas estudiadas. Mientras en Ecuador los términos del intercambio se han deteriorado en alrededor de 38%, en Colombia se han mantenido prácticamente iguales, y en Perú han mejorado sustancialmente cuando se comparan datos de 1970 y 2007. En Perú, la brecha en la relación de intercambio que alcanzaba un factor de 4 en 1970 queda prácticamente eliminada en 2007. Aunque en términos corrientes los productos industriales que se importan en esta región tienen precios más altos que los productos primarios que se exportan, en Perú los precios de las exportaciones han crecido mucho más rápido que los precios de las importaciones, tal como se observa en la tabla 3. Habrá que evaluar lo ocurrido en 2008 y 2009, al caer los precios de las materias primas.

**Tabla 3: Evolución de los términos del intercambio en los países andinos por quinquenios**

**Dólares por tonelada a precios de 1970**

| *Período* | *Colombia* | | *Ecuador* | | *Perú* | |
|---|---|---|---|---|---|---|
| | *Precio X* | *Precio M* | *Precio X* | *Precio M* | *Precio X* | *Precio M* |
| 1970 | 100,00 | 100,00 | 100,00 | 100,00 | 100,00 | 100,00 |
| 1975 | 371,66 | 147,32 | 95,63 | 356,70 | 199,76 | 140,69 |
| 1980 | 867,96 | 144,67 | 240,26 | 467,49 | 452,93 | 294,40 |
| 1985 | 377,79 | 123,97 | 189,50 | 285,87 | 524,06 | 235,19 |
| 1990 | 205,01 | 170,36 | 173,72 | 398,65 | 541,46 | 190,44 |
| 1995 | 232,42 | 213,24 | 184,27 | 592,79 | 536,90 | 233,34 |
| 2000 | 192,88 | 171,15 | 199,02 | 473,74 | 697,82 | 208,98 |
| 2005 | 253,20 | 244,99 | 299,52 | 658,45 | 1.074,09 | 260,80 |
| 2007 | 304,15 | 303,18 | 424,48 | 687,86 | 1.332,10 | 346,16 |
| Cambio en TI | 1,00 | | 0,62 | | 3,85 | |

Elaboración propia

El caso de Ecuador en particular, muestra que existen países que se encargan de la provisión de recursos fundamentales para el funcionamiento metabólico de las economías industriales, pero que ganan poco de dicho intercambio en términos relativos. De hecho, cuando se toman en cuenta los costos sociales y ambientales de la explotación de recursos naturales como el petróleo, se observa que la estructura del intercambio comercial genera perjuicios para esta economía. Aunque las tendencias que se registran en los términos del intercambio de Perú muestran ciertos avances, los costos ambientales y sociales de las exportaciones son también grandes, aunque esos pasivos no se contabilizan.

## 5. ¿Cuáles son los determinantes del uso de recursos materiales?

En esta segunda parte del documento, se analizan los determinantes del uso de recursos materiales en una escala global. Aunque existen notables diferencias en los patrones de uso de materiales de las economías extractivas y no extractivas, un condicionante adicional de las asimetrías estructurales en el uso de materiales serían las divergencias entre economías con diferentes niveles de ingresos per cápita. Mientras las economías extractivas avanzan hacia el agotamiento irreversible de sus recursos naturales, las economías con altos ingresos muestran mejoras internas en términos de sustentabilidad en un sentido débil, pues emplean una menor cantidad de materiales en la producción o se desmaterializan. No obstante, la importación de materiales constituye un factor cada vez más importante para su funcionamiento metabólico. De esta forma, las presiones ambientales que se derivan de la extracción de recursos se trasladan progresivamente desde las economías industriales hacia las economías extractivas (Giljum 2006).

A partir de las cifras de Krausmann et al. (2008) en esta sección se analizan los determinantes del uso doméstico y exportación de materiales de economías con diferentes características estructurales, y para diferentes escalas de uso. Se demuestra que existen diferencias estadísticamente significativas en un rango de la distribución de la extracción y consumo de materiales entre economías de altos ingresos y economías de bajos ingresos, siendo el PIB per cápita uno de los principales determinantes. Asimismo, se estiman diferencias significativas en los patrones de exportación de materiales entre economías extractivas y no extractivas.

### *5.1. Un modelo econométrico de cuantiles*

En esta sección se desarrolla un análisis econométrico con regresiones de cuantiles (Koenker y Bassett 1978), que muestran las diferencias en el uso de materiales en cada percentil de esta distribución a escala global durante el año 2000. La forma funcional que se aplica es la siguiente:

$$ln\,(uso\ de\ materiales\ pc_i) = \alpha\, log(PIB\ pc) + \beta\, log(PIB\ pc) \cdot D_i + \delta \cdot D_i + X_i\, \gamma + \varepsilon_i + \theta$$

en donde, *uso de materiales* $pc_i$ corresponde a la extracción doméstica per cápita de cada país *i*.

$D_i$ es una variable dummy que define a las economías de altos ingresos como $D_i = 1$.

$X_i$ contiene las variables explicativas que determinan el uso de materiales. Estas variables se detallaron en la tabla 2.

$\gamma$ es un vector de parámetros.

$\alpha$ refleja la elasticidad del uso de materiales respecto del PIB per cápita en las economías de bajos ingresos. Esto es, cuando $D_i=0$.

$\alpha+\beta$ refleja la elasticidad del uso de materiales respecto del PIB per cápita en las economías de altos ingresos. Esto es, cuando $D_i=1$.

$\varepsilon_i$ es una variable aleatoria que incluye otros factores que determinan el uso de materiales pero que no son explicados por las variables independientes de este modelo.

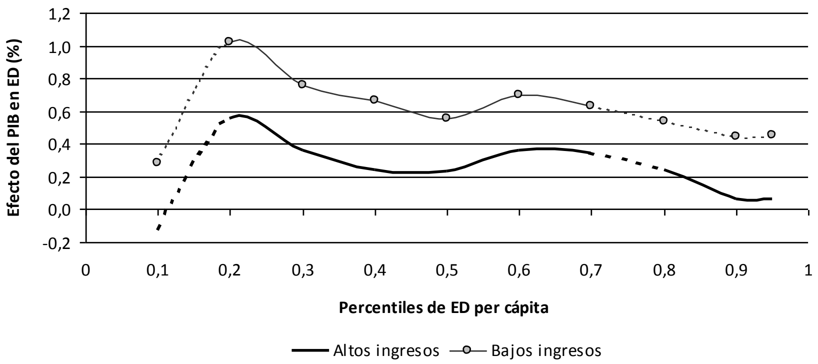
$\theta$ es una constante

No obstante, en esta especificación pueden existir algunos problemas. Al menos tres tipos de sesgo deberían considerarse. En primer lugar, el sesgo por la omisión de variables no observadas que se hallan correlacionadas con las variables explicativas. En segundo lugar, el sesgo por causalidad simultánea entre la variable explicada y una o más variables explicativas, en cualquiera de las direcciones; esto es, bien la extracción doméstica puede ser explicada por el ingreso per cápita o viceversa. Finalmente, un sesgo por errores de medición en las variables explicativas. A fin de corregir estos sesgos, se emplea el método de variables instrumentales. En este caso, se ha identificado como instrumento la escolaridad, medida por la población en cada país con niveles de educación primaria, secundaria y terciaria.[23] Este grupo de instrumentos es válido porque el nivel de educación en un país no afectaría a la extracción doméstica de recursos, pero habría un efecto de la educación en el ingreso per cápita.

[23] De acuerdo a este método, la regresión $Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$. debe dividirse en dos partes. En la primera, $X_i$ puede hallarse correlacionada con $\varepsilon_i$., mientras que en la segunda no. La variable instrumental $Z_i$ no puede estar correlacionada con $\varepsilon_i$ y debe existir correlación entre $Z_i$ y $X_i$. Entonces, se realizan estimaciones en dos etapas: En la primera, la regresión de $X_i$ sobre $Z_i$, a fin de obtener una estimación de $X_i$. En la segunda etapa, la regresión de $Y_i$ sobre la estimación de $X_i$.

Los resultados de esta aplicación se presentan en la tabla 4, detallando sólo las variables con efectos estadísticamente significativos. Uno de los determinantes más importantes es el PIB per cápita, cuyos efectos en la ED se presentan en el gráfico 7, en donde el rango significativo inicia a partir del segundo decil, y son positivos a lo largo de toda la distribución.

**Gráfico 7: Efectos del PIB en la ED**




*Nota:* Las secciones punteadas no son estadísticamente significativas

***Tabla 4: Determinantes del uso de materiales***

***Variable dependiente: Log (ED per cápita)***

| *Variables* | *Deciles* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***0,1*** | ***0,2*** | ***0,3*** | ***0,4*** | ***0,5*** | ***0,6*** | ***0,7*** | ***0,8*** | ***0,9*** | ***0,95*** |
| ***Log (PIB pc)*** | 0,2877 | 1,0183 | 0,7611 | 0,6621 | 0,5528 | 0,7036** | 0,6297* | 0,5355 | 0,4485 | 0,4525 |
| ***Altos ingresos □ log (PIB pc)*** | -0,4033 | -0,4625* | -0,3982** | -0,4202** | -0,3171** | -0,344** | -0,2872 | -0,2905 | -0,3852* | -0,3931* |
| ***IDH*** | 0,5918 | -0,6056 | 0,0834 | 0,2247 | 0,4441 | 0,2376 | 0,6907 | 1,0176 | 1,1308* | 1,1162 |
| ***Log (M materiales pc)*** | 0,0995 | 0,0256 | 0,0761 | 0,0285 | 0,0032 | -0,0233 | 0,0415 | 0,0324 | 0,0864* | 0,0824 |
| ***Energía biomasa pc*** | 0,003*** | 0,003*** | 0,003*** | 0,003*** | 0,003*** | 0,004*** | 0,0025** | 0,0032** | 0,004*** | 0,005*** |
| ***Energía fósil pc*** | 0,001*** | 0,001*** | 0,0006*** | 0,0006*** | 0,0005*** | 0,0005*** | 0,0005*** | 0,0006*** | 0,0007*** | 0,0007*** |
| ***Economías extractivas*** | 0,0341 | 0,0376 | 0,0308 | 0,0393 | 0,0309 | 0,0684 | 0,1348 | 0,1748* | 0,2498** | 0,2522** |
| ***Economías de altos ingresos*** | 3,7771 | 4,192** | 3,6715** | 3,8961** | 2,9659** | 3,1564** | 2,6396 | 2,6693 | 3,4392* | 3,5* |
| ***Constante*** | -1,1884 | -3,2278 | -2,0064 | -1,9297 | -1,6287 | -2,1433** | -1,6752 | -1,6445 | -1,9204 | -1,986 |
| Observaciones | 151 | 151 | 151 | 151 | 151 | 151 | 151 | 151 | 151 | 151 |
| Pseudo $R^2$ | 0,6707 | 0,6977 | 0,7154 | 0,7176 | 0,7189 | 0,7208 | 0,7322 | 0,7498 | 0,7808 | 0,8162 |

Variables no significativas en ningún percentil: Exportación US$ per cápita, Importación US$ per cápita, deuda externa per cápita, territorio disponible por habitante, territorio agrícola per cápita, población urbana, población agrícola, exportación de materiales per cápita, hidroenergía,

Errores estándar entre paréntesis

* Significativo al 10%; ** Significativo al 5%; *** Significativo al 1%

Se calcula que para los niveles más bajos de extracción de materiales, el incremento del PIB per cápita en 1% determina un incremento en la ED de aproximadamente 55% en las economías ricas, y de 102% en las economías más pobres con ingresos bajo el promedio. No obstante, estos efectos disminuyen hasta el quinto decil, luego del cual se inicia otra etapa de incremento que sólo es significativa hasta el séptimo decil en el caso de las economías de bajos ingresos con alrededor de 63%. En las economías ricas, por otro lado, en los dos últimos deciles hay una disminución del efecto del PIB sobre la ED, que llega al 5%. Los efectos en el caso del CDM son sólo significativos en el tercer y cuarto decil. Son efectos positivos que crecen en estos dos deciles.

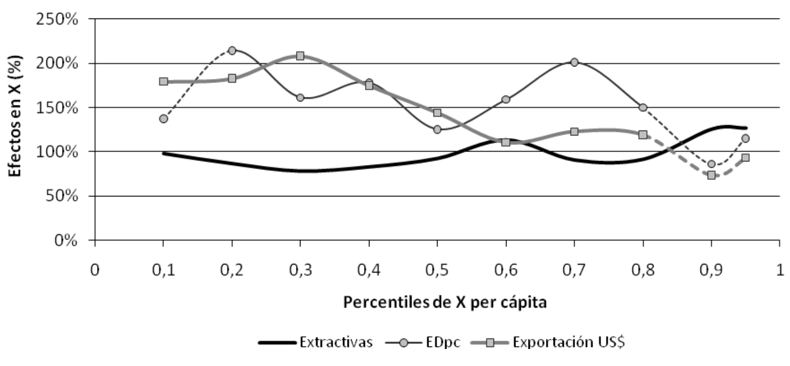
Estas relaciones se explican mejor a través de la llamada *Curva Ambiental de Kuznets.* Esta curva, introducida originalmente por Simón Kuznets (1901-1985) para analizar la relación entre la desigualdad en la distribución del ingreso y el crecimiento económico, fue posteriormente aplicada para explorar cuestiones ambientales Banco Mundial (WB,1992), Grossman y Krueger (1991), Selden y Song (1994), Shafhik y Bandyopadhyay (1992). La hipótesis detrás del análisis con la curva ambiental de Kuznets es que existe una relación en la forma de una "U" invertida entre el ingreso per cápita y un conjunto de emisiones contaminantes (óxidos de nitrógeno, de azufre, partículas suspendidas y plomo). Aunque en las primeras fases del desarrollo hay crecientes presiones ambientales, conforme se incrementa el ingreso per cápita se generarían excedentes de ingresos cuyo destino favorecería la protección ambiental. Entonces, después de llegar a un punto máximo de deterioro ambiental, las economías con cierto nivel de ingresos podrían desarrollarse sosteniblemente reduciendo sus presiones sobre el ambiente. Lo que se observa en los resultados por percentiles para las economías tanto de altos como bajos ingresos (gráfico 7) es que no existe un "efecto Kuznets" en el uso de materiales. El crecimiento económico medido a través del incremento del PIB per cápita genera una creciente extracción y consumo de materiales tanto en economías ricas como en economías pobres. Se trata de presiones ambientales que aumentan a un ritmo decreciente conforme se considera un nivel más alto de uso de materiales.

Otros determinantes importantes que explican la ED son las diversas fuentes de energía. En este caso no se registran efectos muy heterogéneos entre los percentiles de la distribución de la ED, y éstos son significativos para toda la distribución. El efecto de un incremento en 1 GJ en la producción de energía proveniente de biomasa, es un incremento en la extracción doméstica que varía entre 0,3% y 0,5% dependiendo del percentil. En el caso de la energía fósil los efectos son más bajos. Respecto del CDM, sólo son significativos los efectos de la producción de energía a partir de biomasa.

Otros determinantes tienen significación sólo para ciertos percentiles de las distribuciones de ED y CDM. Es el caso del índice de desarrollo humano, la importación per cápita de materiales, los ingresos por exportación, y el territorio disponible por habitante. Otros factores no tienen significación para ningún nivel de ED o CDM, es el caso de las importaciones monetarias, la deuda externa, y el territorio agrícola per cápita.

Finalmente, en la tabla 6 se presentan los determinantes significativos de la exportación de materiales. En este caso, no se observan diferencias significativas entre economías de altos y de bajos ingresos para ningún nivel de exportación. En cambio, se cuantifican diferencias importantes entre economías extractivas y no extractivas para todos los niveles de exportación de materiales. La exportación de las economías extractivas es 2 veces más grande (98% más) que la exportación de las economías no extractivas hasta el primer decil, para el resto de percentiles esta diferencia crece hasta llegar a un factor de 2.3 en el último decil.

**Gráfico 8: Efectos del PIB en las exportaciones**




*Nota:* Las zonas punteadas de las curvas muestran los percentiles que no resultan ser estadísticamente significativos.

La ED per cápita y los ingresos por exportaciones son también factores que explican los flujos de exportación de materiales. Un incremento de 1% en la ED tiene efectos significativos desde el segundo hasta el octavo decil de la exportación de materiales. No obstante, son resultados muy inestables para cada decil, que fluctúan en alrededor de

125% y 214%. Por otra parte, un incremento en los ingresos por exportación determina un efecto positivo en las exportaciones físicas. Estos resultados disminuyen progresivamente. En el gráfico 8 se pueden analizar los efectos por percentiles.

## 6. Conclusiones

La exploración de los perfiles metabólicos de las economías andinas analizadas permite identificar importantes diferencias en términos de escala y composición de sus flujos de materiales. Por una parte, Colombia y Ecuador muestran niveles muy similares de extracción y consumo, mientras que en Perú la explotación minera tiene efectos considerables en términos de intensidad material. En esta economía se incrementa la intensidad material del uso de recursos por unidad de producción económica. Este desempeño tiene importantes implicaciones en términos de la sostenibilidad a largo plazo, pues la base material de su desarrollo son recursos agotables. Un destino similar se podría esperar para Ecuador y Colombia, en donde habría una transición socio-ecológica de la economía hacia el sector no renovable. Estas economías en pleno proceso de crecimiento, continuarán incrementando el uso de materiales. Tanto por los requerimientos nutricionales de una población que sigue expandiéndose aunque a un ritmo más lento que el crecimiento material, como por la necesidad de ampliar la infraestructura material disponible en una economía que se desarrolla.

Ni la exportación ni la importación de materiales son determinantes significativos del uso de materiales en la escala global. Sin embargo, existe una importante dependencia de las economías de altos ingresos respecto de los materiales que se importan, esto es, la quinta parte de los materiales que se utilizan en las economías ricas son importados, mientras que las economías extractivas exportan las dos quintas partes de sus materiales. Por otra parte, Ecuador y Colombia, en la región andina, exportaron la quinta parte de sus materiales, mientras que sólo importaron un 4%. En Perú se exportaron e importaron pequeñas fracciones de materiales 4% y 3%, respectivamente en el año 2000, cuando también se analiza la escala global.

No se identifican efectos en el sentido de “Kuznets” para economías de altos ni de bajos ingresos. Los efectos de un incremento del PIB en la extracción son positivos para todos los estratos del uso de materiales. Esto implica que las economías en realidad no se desmaterializan con el crecimiento.

## CONCLUSIONES GENERALES

Las principales conclusiones de este trabajo son que estas tres economías estructuralmente tienen características similares, y coinciden en un intercambio desigual de flujos de materiales en el comercio mundial debido a la especialización en actividades extractivas primarias y a la salida neta de recursos materiales. Todas ellas tienen balances físicos negativos en su comercio exterior, exportan mucho más de lo que importan. Compran caro y venden barato. Pero las tres economías difieren en la composición de sus flujos de materiales y en su escala. En particular, en el caso de la economía peruana las diferencias se deben a la carga material de la industria minera en ese país, mientras que Ecuador y Colombia mantienen estructuras todavía dependientes mayormente del uso de biomasa aunque el primero exporta mucho petróleo y el segundo mucho carbón mineral. Perú no se está desmaterializando ni tan solo en términos relativos al PIB.

En las tres economías andinas, tanto la extracción doméstica de materiales como el consumo doméstico muestran continuos incrementos entre 1970 y 2007. Se cuantifican incrementos cercanos a un factor de 4 tanto en Colombia, como en Ecuador y Perú durante este período. En términos relativos, los resultados difieren un poco. Mientras en Ecuador y Colombia la extracción y consumo de materiales por unidad de PIB disminuyen con el transcurso de los años, esto es, se registra una desmaterialización relativa; en Perú existe incluso en términos relativos una tendencia creciente en el uso de materiales.

Respecto de los conflictos ecológico-distributivos, el análisis de los indicadores de flujos de materiales permite concluir que muchos conflictos por la extracción de recursos o la contaminación están estrechamente ligados al creciente metabolismo social que determinan los patrones de uso doméstico o exportación de materiales. Estos flujos son medidas de las presiones ambientales que las actividades económicas ejercen en la naturaleza, debido al agotamiento progresivo de recursos no renovables, e incluso debido al deterioro de recursos renovables que en algunos casos se explotan a ritmos que superan su tasa de regeneración natural.

Estos resultados constituyen una línea de base para evaluaciones de la sustentabilidad a largo plazo de estas economías. En particular si existen planes de expandir el uso de fuentes no renovables de materiales como en el caso ecuatoriano, en donde se debate el inicio de actividades mineras a gran escala además de la explotación de petróleo en zonas de alta sensibilidad ecológica y social, o si se va a ir a una transformación productiva menos primario-exportadora y que use fuentes renovables de energía y materiales que no entren en contradicción con las poblaciones que habitan en las zonas de explotación.

Existen al menos dos signos de la llamada “maldición de la abundancia de recursos”. El primero es la extracción creciente de materiales; y, el segundo son los crecientes conflictos ecológico-distributivos. Aunque la desmaterialización relativa en Ecuador y Colombia muestra que el producto económico crece más rápidamente que el uso de materiales. Ciertamente, esta “virtuosa” tendencia hacia la desmaterialización relativa puede continuar hasta el agotamiento completo de ciertos recursos, momento en el cual se verificará un colapso económico si no se planificaron sustitutos renovables. Un crecimiento basado en recursos agotables como el petróleo o minerales no permite tener perspectivas de largo plazo. En este contexto cabe entonces preguntarse si ¿estas economías habrán formado una inversión suficiente para sustituir recursos que inexorablemente se agotarán?

La transición socio-ecológica se analiza en el caso ecuatoriano. La mayoría de sus “rasgos metabólicos” identifican a esta economía en una lenta transición hacia un régimen industrial. Tanto hoy como hace 40 años, la biomasa continúa siendo la principal base material de esta economía (79% del CDM per cápita en 1970 y 38% en 2007), aunque ha decrecido con los años. El sector de la construcción se ha expandido, y actualmente representa casi la misma fracción que la biomasa (36% en 2007). Para los próximos años se puede esperar que el crecimiento económico sea acompañado por un crecimiento significativo en el uso de fuentes no renovables de materiales y energía, aún tomando en cuenta que el crecimiento poblacional está disminuyendo. Dado que las reservas de petróleo se agotan, es necesario un cambio en la estructura económica.

En cuanto a investigación futura, para la construcción de una teoría del intercambio ecológicamente desigual hace falta complementar la información aquí presentada con los flujos indirectos del uso doméstico de materiales y los flujos indirectos asociados a la importación y exportación, concretando de esta forma los balances de materiales. Adicionalmente, la dimensión material de la evaluación socio-metabólica de estas economías se debería complementar en futuros trabajos con los flujos de energía en un análisis integrado, ya que por ejemplo una economía puede desmaterializarse a la vez que aumenta su uso de energía al emplear más hidroelectricidad, y esos datos tanto de materiales como de energía son necesarios para caracterizar su perfil metabólico según va cambiando. Asimismo, la investigación futura podría incluir el análisis de la HANPP (apropiación humana de la producción primaria de biomasa) y de los flujos de agua "virtual" como ya se empezó a estudiar para el caso del banano (Vallejo 2006a). Así, en el futuro podría seguir también los pasos de Falconí (2002) trazando evaluaciones multi-criteriales (con indicadores físicos como los reseñados, además indicadores sociales y también económicos como el PIB) del desempeño de esas y también otras economías en distintos momentos históricos y en el futuro. Asimismo resulta interesante continuar con el estudio de la relación entre metabolismo social y conflictos ambientales cuya visibilidad social y política es cada vez mayor, como es el caso de Perú.

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