Metabolic Profile of the Colombian Economy from 1970 to 2007

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ecologically unequal exchange
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societal metabolism

Summary

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 flow 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 and growing negative physical trade balance, whereas per capita use of materials is still about half of the industrial countries' average.

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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-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 economies, which is omitted in conventional macroeconomic indicators. It helps to illuminate the linkages between the course of development and material use patterns, quantify progress toward a sustainable use of resources by improvements in material efficiency (or reductions in 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 (Schnaiberg et al. 1986; Blaikie and Brookfield 1987; Berkes 1989; Ostrom 1990; Greenberg and Park 1994; Martinez-Alier and O'Connor 1996; Martinez-Alier 2002; Robbins 2004). 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—for instance, 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 of 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, we have used a simple systemic model 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 (MFAs) 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 extends the previous work 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 was a marked change in world extraction and trade of materials in 2008–2009 because of the global financial crisis. This article gives a baseline to chart the future pattern of the Colombian economy in 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 systematic links between Colombia's metabolic profile (Schandl and Schulz 2002)—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. Like 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; Sachs and Warner 1995, 2001; Gavin and Hausmann 1998). 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 sociometabolic patterns. Results of the study are presented in the fourth section, which is divided into subsections 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.

Methodology and Information Sources

Definitions and Methods

This article introduces "satellite" accounts for Colombia, which extend the conventional System of National Accounts by physical indicators, as proposed in work by the United Nations (2003) and by Pedersen and de Haan (2006, 2009). The physical indicators employed are domestic extraction (DE), direct material input (DMI), domestic material consumption (DMC), 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., technologies 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. This 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, we define PTB 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 tonnes.[1]

MFAs computed in this article are based on the methodological guides of EUROSTAT (2001, 2002, 2007).[2] More recently, the 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. This research has not been concerned with unused extraction, indirect flows, or sectoral disaggregation of material flows, which are not yet standardized.

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 afterward officially reported to international offices. Even if certain weaknesses of the data persist because some flows are underestimated or not reported in official statistics—such as 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 among sources, however, makes it difficult to generate reliable annual estimates.[3] In addition, these flows are not significant in terms of tonnage—less than 0.3% of DE of primary crops. Their manufacture (cocaine and heroin) is an important part of 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.

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 (2009b)
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); UNSD (2009b); USBM (2009)
Fossil fuels	Production of fossil fuels.	OLADE (2007) compared to OPEC (2007)

Source: Authors' elaboration.

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.[4] Biomass from hunting is not accounted for because of the lack of regular reports disaggregated at this level and the small contribution of volumes obtained through estimations.[5]

Comparisons of different international data sources and studies indicate an underestimation in building materials statistics by the U.S. Bureau of Mines (USBM). These accounts are calculated according to a recently proposed method (Krausmann et al. 2009) that is based on cement and bitumen production figures.[6]

The Colombian Economy: An Overview

Colombia occupies relatively high positions in several dimensions of the international rankings. It is the 33rd largest economy in the world in terms of gross domestic product (GDP) at purchasing power parity (PPP; Heston et al., 2009). Its geographical area of 1.1 million square kilometers (km^2) makes it the 25th largest country, but with only 39 inhabitants/km^2 (WB 2010).[7] 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, one of the group of countries with medium-level human development (UNDP 2010).

On analyzing the country's economic activity, we found that total GDP at PPP prices in 2005 constant dollars rose at an annual rate of 3.9%

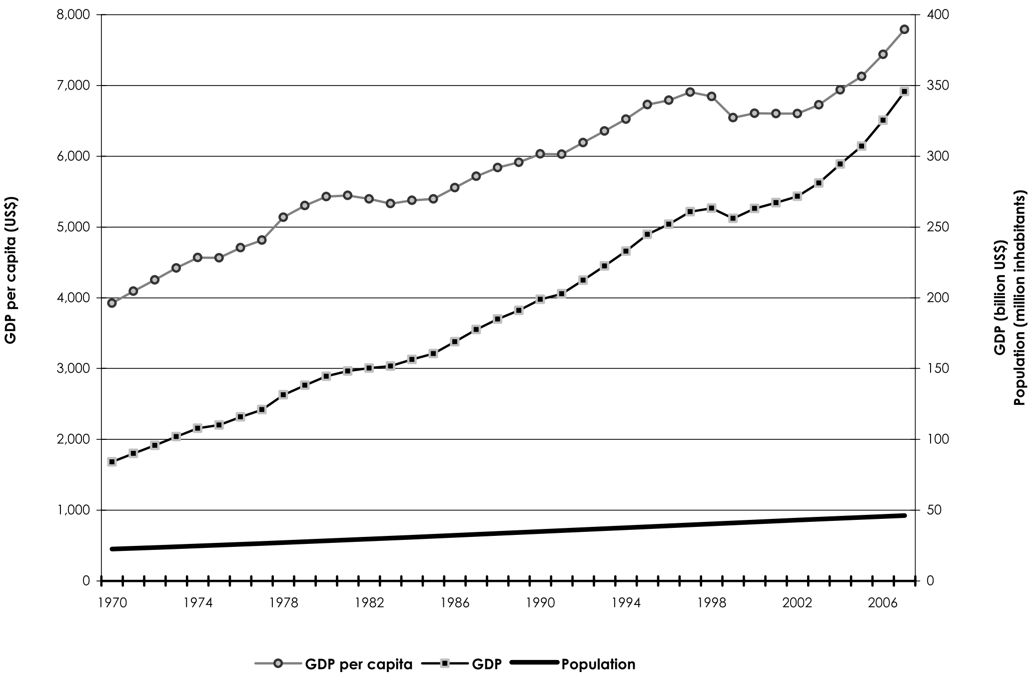

Figure 1 Trends in the economy and population, Colombia (1970–2007). Gross domestic product (GDP) figures are given in purchasing power parity (PPP) dollars at 2005 constant prices. *Sources:* Penn World Table 6.3 from Heston and colleagues (2009); CELADE (2009).

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 2009a), its growth rate is now quickly decreasing. The average annual growth for the period was 2%. Figure 1 shows the evolution of these variables.

After Colombia followed the import substitution economic policy common to most of Latin America through 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 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 economic openness. As a 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.

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.

Trade Relations and Inequalities

The Physical Trade Balance

As shown in figure 2, the volume of physical exports increased notably during the period 1970–2007, from about 7 megatonnes (MT; or

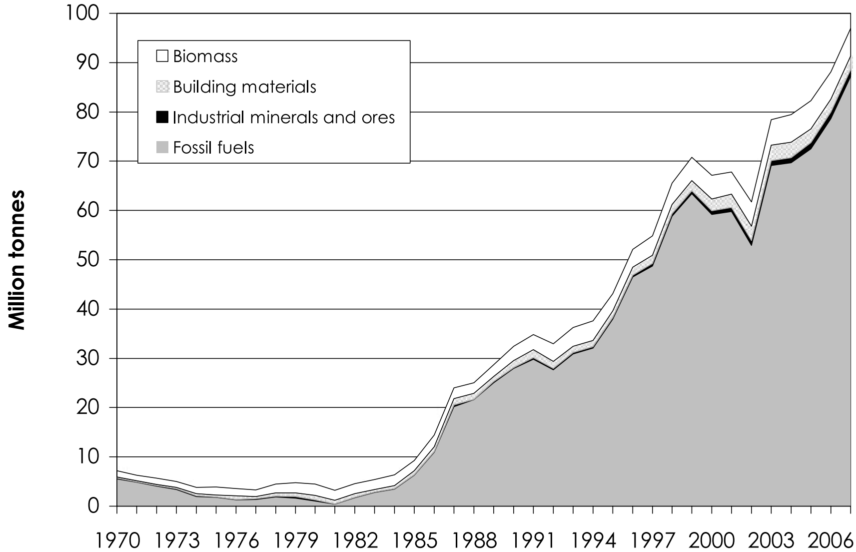

Figure 2 Physical exports of Colombia (1970–2007). *Source:* Authors' estimations.

million tonnes) to around 97 Mt,[8] an annual growth rate of 7.3%, much higher than the monetary growth rate of 3.9% in constant terms. A significant upward cycle began 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 for export 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. The share 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.

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 an economic crisis in the country, recovering after 2002.

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. 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 semimanufactured goods.[9] This is a regular pattern for small economies founded on the export of raw materials domestically extracted, with a limited scope of the domestic productive chains.

This assessment, however, does not include indirect flows. The so-called "raw material equivalents" (RMEs; Eurostat 2001; Weisz et al. 2006) are not accounted for—that is, the upstream material requirements of used extraction (intermediate inputs) associated with imports or exports. Muñoz and colleagues (2009) determine that the Colombian deficit in the PTB doubled when the raw material trade balance was estimated, from 62 to 123 Mt. Each tonne exported by Colombia needed about 1.3 tonnes of indirect flows that remained in the country in the form of wastes and emissions—a larger amount in the aggregate compared with imports—whereas each tonne

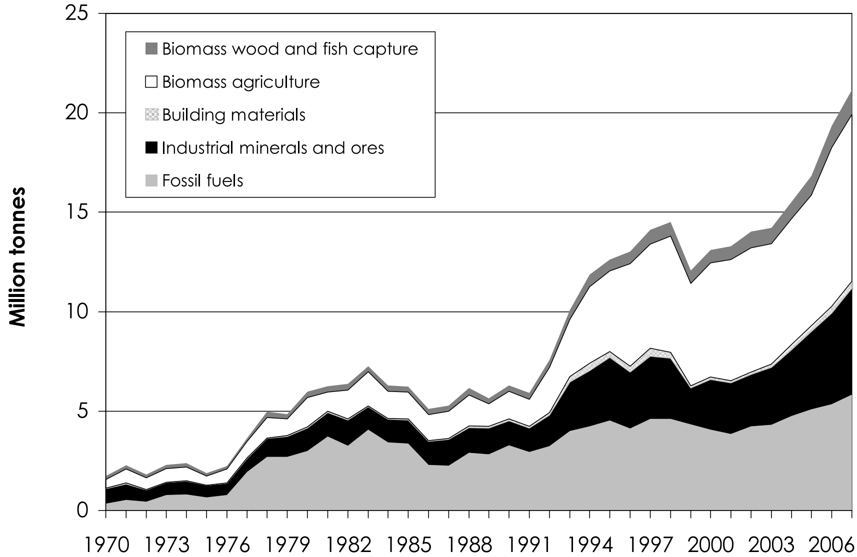

Figure 3 Physical imports to Colombia (1970–2007). *Source:* Authors' estimations.

imported required the movement of 2.9 tonnes of indirect flows in the country of origin.

Are Terms of Trade (TOT) Improving?

The concept of economically unequal exchange was popularized in the 1960s by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) 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

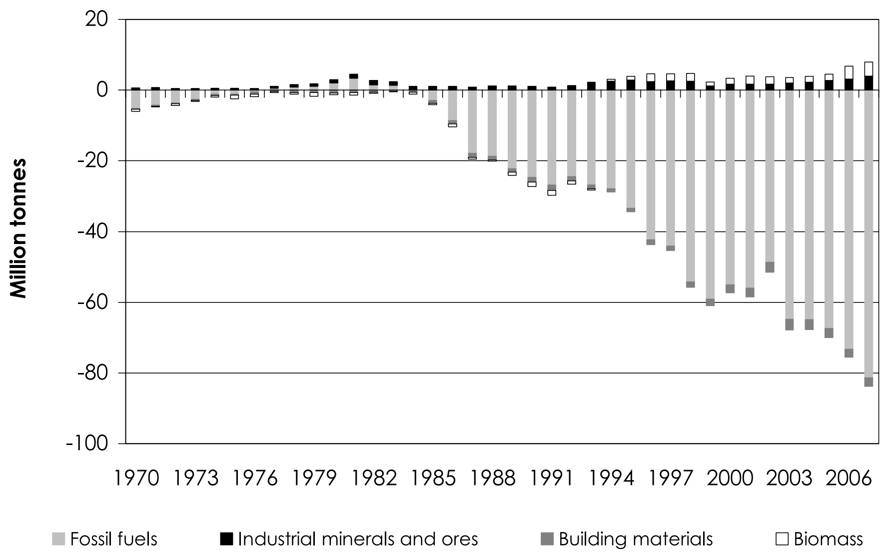

Figure 4 Physical trade balance of Colombia by material component (1970–2007). *Source:* Authors' estimations.

the strong negotiation power of unions. Conversely, productivity improvements in the "peripheral economies" result in lower prices because of ample supplies of labor and because of competition among product sellers—notice, for instance, that the Organization of the Petroleum Exporting Countries (OPEC) is the only successful export cartel. As a result, many hours of underpaid work are embodied in primary products exported from the periphery, which are traded for 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. Along this line of thought, 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 centers. 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. 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 (Hornborg 1998; Muradian and Martinez-Alier 2001; Giljum and Eisenmenger 2004), 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, which means 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 at constant prices (base year 1990). Export prices are lower than import prices, even during the coffee price peak of the 1970s, caused largely by a failure of the Brazilian crop. A sixfold improvement in TOT was registered by 1981, which was followed by a substantial decline in exports' unit values and a long period of stagnation even during the high commodity prices registered in the 2000s—the subsequent decline since mid-2008 is outside the scope of this analysis. Notice that when prices of essential bulk commodities (e.g., 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 evidence of deterioration in TOT. Thus, export prices declined 1.7 times (from US$340 to US$202), and import prices declined 1.3 times (from US$2,233 to US$1,710).[10]

A Domestic Profile

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, agroecosystems, grasslands, mangroves, coral reefs, wetlands, Andean forests, and moors, in addition to 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%) and by agricultural lands and pastures (38%).

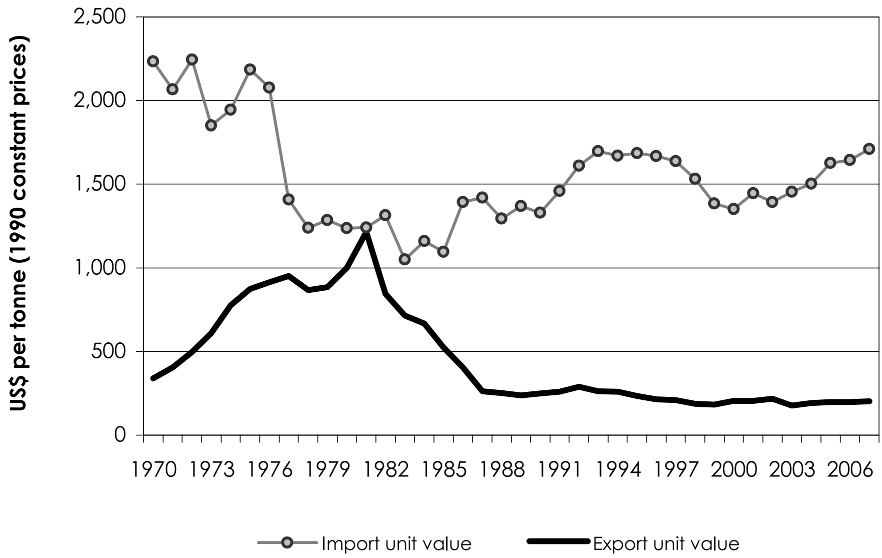

Figure 5 Unit value of foreign trade flows, Colombia (1970–2007). *Sources:* UNSD (2010) and authors' estimations.

Figure 6 shows DE from 1970 to 2007 by material component. A threefold increment from 136 to 392 Mt was registered. The annual 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.

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 the La Loma mine. Crude oil is the second fossil fuel

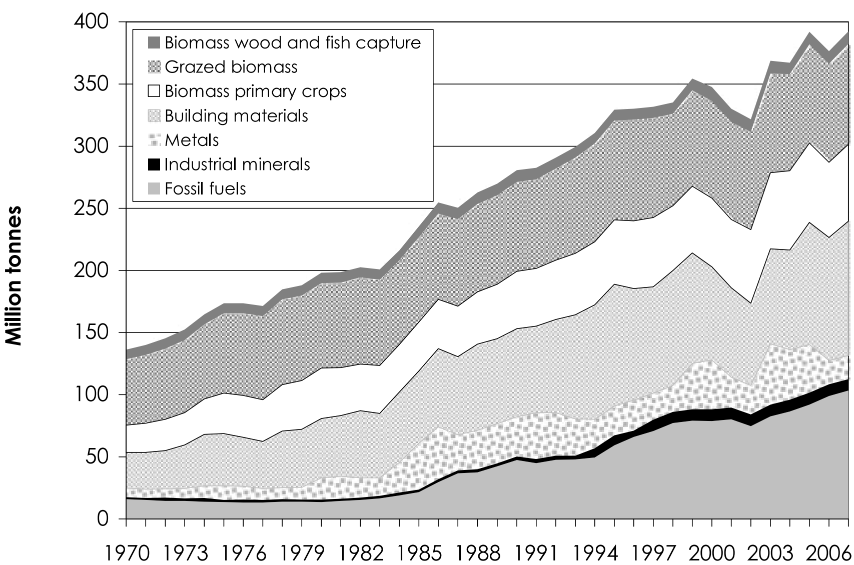

Figure 6 Domestic material extraction of Colombia (1970–2007). *Source:* Authors' estimations.

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, loss of biodiversity, gas flaring, and other severe environmental impacts, which furthermore jeopardize health conditions and chance of survival for the people living in the mining areas.

For instance, the ancestral community of Yariguies disappeared with the crude oil exploitation of Exxon-Esso in Colombia—there are no more references to its existence after the 1920s. Likewise, the Motilones Bari communities undertook various resistance actions against Mobil's activities; however, by the late 1960s, only 60% of the original population was living on less than one-fourth of the territory initially occupied (Roldan 1995). The Standard Oil Company affected about 100,000 hectares of virgin forests,[11] 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, has been operating inside the area.

As coal extraction releases toxic pollutants into the air, water, and soil, it is known as the dirtiest of all fuels. The Wayuu indigenous communities, which comprise about 145,000 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,[12] where the product is shipped for export. The Wayuus' complaints emerge because of health damage and livelihood losses due to accidental death of goats on railway 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 moderate pattern of growth. The number of cattle heads increased 1.3 times, and other types of livestock almost doubled in number. Around 1 million extra hectares were converted to permanent meadows and pastures by 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 have also been usurped to establish illegal crops.

Biomass from primary crops increased consistently by almost threefold by 2007 (22 Mt to 62 Mt). Permanent crops for export displaced some temporary crops meant for domestic consumption. This was the case for cereals, roots, and tubers, whose participation in primary crop extraction diminished from 19% to 13% by 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 two times more land than in 1970—515,000 and 450,000 hectares, respectively—whereas oil palm plantations, a new crop, has currently surpassed 165,000 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 postharvest). This conflict is worsened by water pollution and health effects because of the use of agrochemicals. Flower crops could employ, on average, 0.5 tonnes/hectare of pesticides in 1 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 with their exploitation.

Colombian forests play a fundamental ecological role, not only as carbon reservoirs and homes for rich biodiversity but also as protectors of vital water resources. Forest wealth, however, has deteriorated. Deforestation during the last 15 years is estimated at 47,400 hectares a year (FAO 2009b).

Deforestation is mainly attributed to the expansion of pastures for grazing and agricultural activities. Other causes are the internal consumption of wood for industrial purposes and, to some extent, fuel wood as a domestic source of energy. Displacement because of the violence of the internal armed conflict and illegal crops establishment are also important factors in deforestation. In 2007, illicit plantations occupied 99,000 hectares (UNODC 2008). Deforestation, however, is higher because the establishment of 1 hectare of coca crop requires clearing 4 hectares of tropical forests (Nivia 2001; Bernal 2003).[13]

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 700,000 hectares of lakes and 20,000 kilometers of rivers. Industrial-scale fishing is developed in oceanic waters, above all for export. Shrimp have been grown industrially, which affects mangroves. Continental fishing was an important source of income and food security for local populations up until the 1980s, when pollution, deforestation, and overexploitation collapsed the activity in the Magdalena River (FAO 2003).

Building materials are in many countries an important part of DE. In Colombia, annual 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—grew from 1.7 to 9.4 Mt. Historically, different governments considered roads and housing policies as fundamental elements for promoting 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 (Weisz et al 2006; Behrens et al. 2007). A higher demand for building materials is promoted because of the infrastructure requirements of growth. Conversely, investment in physical infrastructure and, therefore, the use of materials declines 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.

For more than 400 years, gold extraction chaotically expanded in Marmato, a traditional small-scale mining district of the Andean region in Colombia. Frequent landslides on 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 30,000 to 60,000 tonnes of land and rocks. The affected community—about 1,000 inhabitants—however, is complaining (OCMAL 2009). This is just one of the many mining conflicts arising. Just what items are considered "preciosities" in the importing countries, such as gold—completely irrelevant to their metabolic flows—have important socioenvironmental 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 policy nor technological change avoids the resulting impacts, which disproportionately affect different social groups. This is the ultimate source of protests and

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	International	Multinational companies, indigenous population	Water, soil, air, biodiversity, forest, traditional knowledge
Coal	Atlantic coast	Bulk commodity	International	Multinational companies, rural and indigenous population, touristic sector	Water, soil, air, human health
Emeralds	Andean region	Preciosity	National and international	National companies, local communities	Water, soil, forest
Gold	Andean region and Pacific coast	Preciosity	International and regional	Multinational and national companies, local communities	Water, soil, air, human health, economic options for local communities
Ferronickel	Atlantic coast	Bulk commodity	International	Multinational companies, local communities	Water, soil, air, human health
Illicit crops (coca, opium poppy)	Amazonia, Orinoquia, Andean and Pacific coast regions	Preciosity	National	National companies and local communities	Water, soil, air, human health, social relationships
Shrimps	Pacific and Atlantic coasts	Preciosity	International and regional	National companies and local communities	Mangroves, water, economic options for local communities
Flowers	Andean region	Preciosity	International and regional	National and international companies and local communities	Water, soil, food security
Sugar cane	Andean region	Bulk commodity	National and regional	National companies and local communities	Water, soil, human health, food security
Banana	Atlantic coast	Bulk commodity	National and regional	National and international companies and local communities	Water, soil, human health
Oil palm	Atlantic and Pacific coast and Orinoquia	Bulk commodity	National and regional	National companies and local communities	Water, soil, biodiversity, forests, food security
Tropical wood	Amazonia, Orinoquia, and Pacific coast	Bulk commodity	National	National and international companies, indigenous and Black communities	Water, soil, biodiversity, forests, cultural values

Sources: Perez-Rincon (2008) and authors' elaboration.

resistance expressed through diverse types of valuation languages (Martinez-Alier 2002, 2009).

Besides the ecological distribution conflicts discussed in this section—those derived from the extraction of oil, coal, extensive monocrops, 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; the table links, therefore, the study of societal metabolism to the study of political ecology (Gerber et al. 2009). On 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.

Domestic Material Consumption

Productive processes are continuously transforming domestic and foreign inputs into products; a fraction of the products become physical exports to the world, and the remaining fraction turn 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 and colleagues (2006) identify DMC as an indicator of the "domestic waste potential."

In the Colombian economy, DMC has increased from 131 to 317 Mt between 1970 and 2007, as shown in figure 7. It implies an annual growth rate of 2.4%. Like in DE, biomass is the main component of DMC, although its share has declined over the years, from 63% to 50%. Grazing has been the most important component of biomass. An important increment, from 22% to 33%, is registered in building materials. Regarding other kinds of resources, no significant changes in terms of structure were recorded, but volumes are currently larger than they were in 1970.

In per capita terms, biomass is also the main component of the DMC. Meanwhile, more industrial minerals and building materials are required; the share of biomass consumption is declining. These figures, as do those of DE, show that a transition toward 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 the 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 the population (2%) between 1970 and 2007.

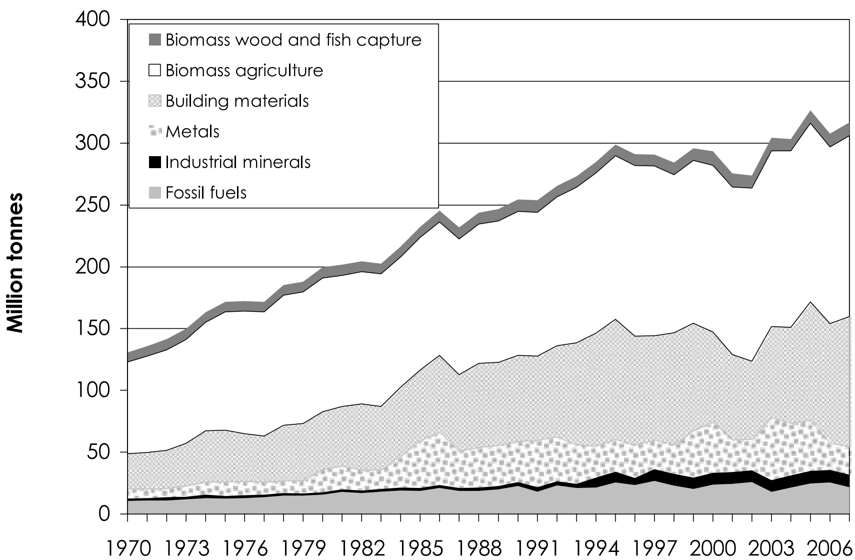

Figure 7 Domestic material consumption of Colombia (1970–2007). *Source:* Authors' estimations.

Table 3 Domestic material consumption of Colombia—tonnes 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	*1970–1974*	*1975–1979*	*1980–1984*	*1985–1989*	*1990–1994*	*1995–1999*	*2000–2004*	*2005–2007*	
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%	

Note: DMC = domestic material consumption.
Sources: CELADE (2009) and authors' estimation.

Comparisons of Scales and Material Intensities

The purpose of this section is to compare metabolic profiles of economies with similar and divergent levels of development, population, and territory. In a first comparison, it is notable that socially and economically similar structures correspond with regard to their 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 in keeping with 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 in both countries have increased since 1970, although by higher rates in Ecuador.

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 hidden flows further support arguments of an ecologically unequal exchange between the economic centers and peripheries and support claims for recognition of the ecological debt from north to south (Machado et al. 2001; Muradian et al. 2002; Pengue 2005; Muñoz et al. 2009).

Finally, MFAs 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 densely and sparsely populated countries.

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 one unit of the

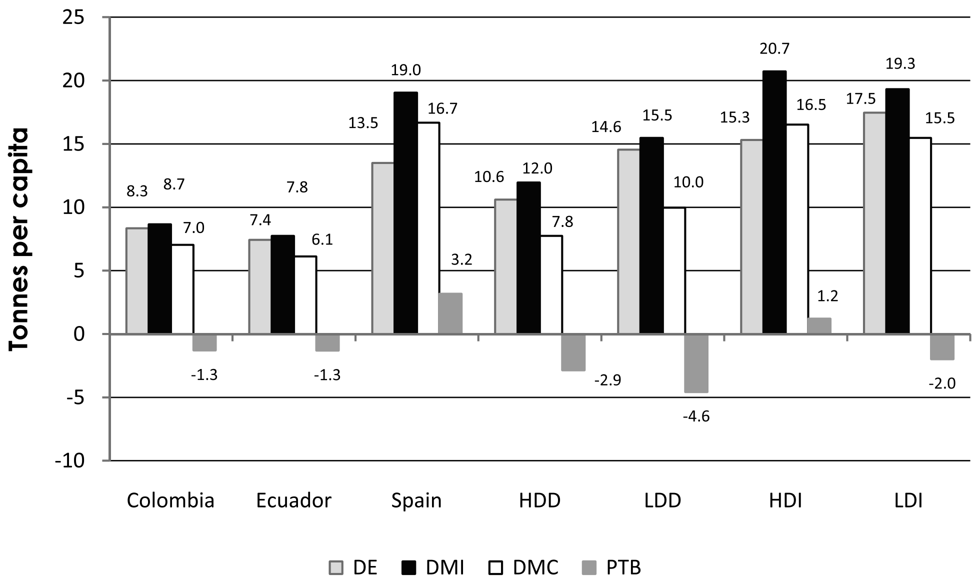

Figure 8 Per capita material flow accounts compared. HDD = high-density developing; LDD = low-density developing; HDI = high-density industrial; LDI = low-density industrial; DE = domestic extraction; DMI = direct material input; DMC = domestic material consumption; PTB = physical trade balance. *Sources:* Krausmann and colleagues (2008), Sojo and colleagues (2007), Vallejo (2010), and authors' estimations.

economic output. The fraction is 73% in the case of DMI. Differences between the intensity of DMI and DMC are explained by export flows.[14] 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 grew 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 diminishing surface of rainforests and a decline of 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 a comparison of MFA indicators and the surface area. The amount of material used per unit of the Colombian land territory increased from 1.2 to 2.9 tonnes/hectare between 1970 and 2007. The Colombian physical economy has expanded with reference to its natural environment more rapidly than countries with similar economic and population structures (2.9 versus 1.8 tonnes/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 tonnes/hectare), highly populated developing countries (14 tonnes/hectare), and high-density developed economies (26 tonnes/hectare).[15]

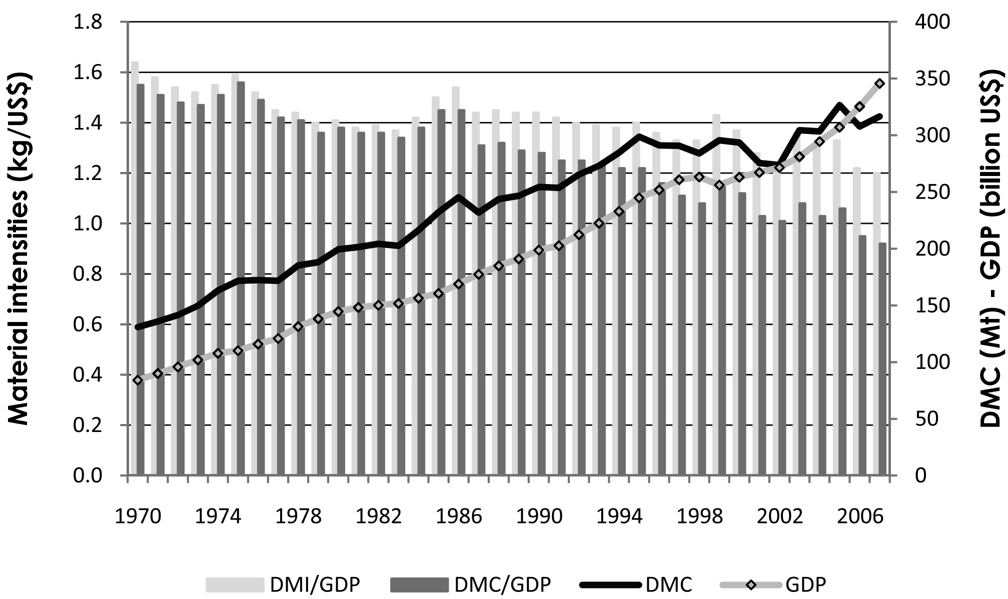

Figure 9 Material intensity trends of Colombia (1970–2007). Gross domestic product (GDP) figures in purchasing power parity (PPP) dollars at 2005 constant prices. kg/US$ = kilograms per U.S. dollar; DMI = direct material input; DMC = domestic material consumption; Mt = megatonnes. *Sources:* Penn World Table 6.3 from Heston and colleagues (2009) and authors' estimations.

Conclusions and Policy Implications

One contribution of this article is the compilation of MFA for the Colombian economy over a nearly 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 and the environmental conflicts related to such pressures, and identifies some of the forces driving such patterns. It provides evidence that supports a theory of "ecologically unequal exchange." At the time of writing, the United Nations' ECLAC is not yet publishing MFAs 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 and colleagues (2008), Gonzalez and Schandl (2008), Perez-Rincon (2006), and Vallejo (2006)—hence the subtitle of Perez-Rincon's (2006) analysis of Colombian international trade: "Toward an Ecological 'Prebisch thesis.'" Prebisch (1950) was the ECLAC's director; he analyzed the deterioration of the terms of trade for primary exports but did not study environmental liabilities.

Ecologically unequal exchange, deteriorating terms of trade, absolute increases in material use, reprimarization of the economy, and 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 are also relevant to the debate on the environmental sustainability of the economy. A baseline of biophysical indicators and environmental conflicts will be useful 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 to cover the metabolic requirements of developed economies (Hornborg 1998), whereas the domestic necessities are frequently relegated. At the same time, the environmental liabilities related to these exploitation patterns are not recognized in market prices. They become visible only through conflicts, and they are evidence 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 has 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 and colleagues (2009), this is a signal of the transition toward an industrial-type social metabolism. Colombia has not developed a large and strong industrial sector, however. Instead of industrializing, the country has expanded extractive and services activities.

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 (e.g., flowers, agrofuels) 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, which in the Colombian context are often solved by violence from the military or illegal groups (guerrillas, paramilitary 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 evidence 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 material use. So there is no resource curse. From a social and political point of view, however, there have been 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, and biomass (Martinez-Alier 2002). Distinctive to Colombia is, unfortunately, the high level of violence.

As in other resource-intensive countries in the south, not just domestic efforts to improve material productivity are required. The total surface area 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.

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 nongovernmental organizations (NGOs), on the model of the Yasuni ITT proposal in Ecuador (Finer et al. 2010; Larrea and Warnars 2009). Industrial economies' compensations could be assessed as avoided environmental impacts, such as deforestation, loss of biodiversity, greenhouse gas emissions, and pollution. Finally, in a stage of transition toward a sociometabolic 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.

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Notes

1. One tonne (t) = 10^3 kilograms (kg, SI) ≈ 1.102 short tons.
2. The 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).
3. Estimations presented by Steiner (1997) show that around 3 thousand tonnes of coca leaves were harvested in 1980 and 30 thousand in 1990. Bernal (2003) reports 115.8 thousand tonnes in 2000, and the USDS (2008) registers more than 154.1 thousand tonnes in 2006. Regarding marijuana and

heroin, Steiner presents export figures: 3.9 thousand tonnes of marijuana and 20 tonnes of heroin annually during the first half of the nineties.

4. The World Bank (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 cubic meters (m^3), which determines a total extraction of 4.4 Mt (megatonnes, or million tonnes) including the illegal activities (assuming a wood density coefficient of 0.85 tonnes/m^3). Contrastingly, FAO figures report 10.1 Mt extracted in the same year, taking into account the domestic consumption of fuel wood, other industrial roundwood, and wood roughly prepared. *Note:* One cubic meter (m^3, SI) $\approx$ 35.3 cubic feet (ft^3).
5. Baptiste and colleagues (2002) present estimations of the indigenous Wuonaan's hunting: about 1.8 tonnes a year of biomass (mammals, reptiles, and birds). This volume (0.2 kilograms per person), extrapolated to the indigenous population of Colombia dependent on hunting (about 154,000 people), determines a total amount of 31 tonnes a year for the whole country.
6. 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 the building materials required for different purposes are accounted from the USBM.
7. One square kilometer (km^2, SI) $\approx$ 0.386 square miles.
8. One megatonne (Mt) = 10^6 tonnes (t) = one teragram (Tg, SI) $\approx 1.102 \times 10^6$ short tons.
9. The PTB disaggregated by the processing level of materials was already presented in the work of Perez-Rincon (2006).
10. This article does not attempt to develop Perez-Rincon's (2006) analysis of the asymmetries in the functioning of labor markets in the center and the periphery (part of the so-called Prebisch's thesis). More information than made available in the present article would be needed for this. Both international and internal aspects are relevant. For instance, more flexible labor markets have also been introduced in the world peripheries in a context of commercial openness and therefore wider salary spreads between qualified and less qualified labor.
11. One hectare (ha) = 0.01 square kilometers (km^2, SI) $\approx$ 0.00386 square miles $\approx$ 2.47 acres.
12. One kilometer (km, SI) $\approx$ 0.621 miles (mi).
13. In addition, other severe environmental impacts affect tropical forests and populations: pollution due to aerial herbicides fumigations used to eradicate crops, and contamination of water sources and soil by the disposal of chemical wastes from drugs processing.
14. $DMI - DMC = (DE + M) - (DE + M - X) = X$.
15. Figures are estimated from work by Krausmann and colleagues (2008) and WB (2010).

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