Recent Trends in Material Flows and Resource Productivity in Latin America

Publication: Recent Trends in Material Flows and Resource Productivity in Latin America
United Nations Environment Programme, Nairobi. Published June 2013
Job Number: DEW/1578/PA

Disclaimer

UNEP promotes environmentally sound practices globally and in its own activities. This publication is only available electronically. Our distribution policy aims to reduce UNEP's carbon footprint.

Recent Trends in Material Flows and Resource Productivity in Latin America

Contents

Acknowledgements

This report results from a collaborative project between the CSIRO and the United Nations Environment Programme (UNEP) regional offices for Asia and the Pacific and Latin America and the Caribbean. The report was written by James West and Heinz Schandl of CSIRO Ecosystem Sciences, who have also compiled and analysed the underlying data.

The authors would like to thank Anna Stabrawa (UNEP Asia and the Pacific, Bangkok), Graciela Metternicht and Elisa Tonda (UNEP Latin America and the Caribbean, Panama City) for their contributions to this document. They are also grateful to Tommy Wiedmann and Karin Hosking (CSIRO Ecosystem Sciences) for respectively reviewing and editing the report and to Professor Joan Martínez-Alier (UAB, Barcelona), Professor Walter Pengue (UNGS, Argentina), Dr Ana Citlalic González Martínez (consultant, Singapore) and Mauricio E. Blanco Redondo (Government of Colombia) for their valuable feedback. Thank you to Peerayot Sidonrusmee for designing this publication.

List of acronyms related to material flows and resource efficiency

DE Domestic Extraction – Materials domestically extracted from the environment which are subsequently used in economic activity

DMC Domestic Material Consumption (= DE – PTB)

GDP Gross Domestic Product

MI Materials Intensity (= DMC / GDP)

PTB Physical Trade Balance (Net Imports – Net Exports)

I Impact (environmental), in IPAT analysis terminology. In this report, the environmental impact considered for the IPAT analyses is extractive pressure, so I = DMC

P Population

A Level of Affluence of the population

T Technological coefficient, in IPAT analysis terminology. This is a measure of the environmental impact (I) generated per unit of income generated. For this study, T = DMC /GDP, and so is equivalent to MI

1. Main Messages

The Latin America region accounts for about 10% of world consumption of primary materials. As a result, developments in this region do not have a major effect on total global extractive pressures. The reverse is not true. Even modest increases in the resources demand of larger regions, where transferred by trade, can have major effects on material flows in Latin America.

The region began the period 1970 to 2008 relatively inefficient at converting its primary resources to income, and became progressively less efficient at extracting value as the period progressed. Examples of individual countries defying this trend, while rare in this region, do exist and merit closer study.

The major increase in commodity prices over the first decade of the 21st century slowed the rate at which the region's resource efficiency declined, but did not reverse it. Any reversion to the declining terms of trade which characterized the later decades of the 20th century would likely see environmental pressures in the region escalate rapidly just to maintain current material living standards.

The rapid increases in population in the region which drove growing environmental pressures in the earlier decades have eased greatly, so that in recent years the main driver has been growth in per capita incomes and the higher per capita consumption levels that engenders.

The findings of this report are based on the first material flows database, which has been specifically designed to cover the great majority of countries in Latin America, as well as additional countries in the Caribbean region, using standardized material flows accounting methodologies.

2. Introduction

This report is based on a material flows database which has been established for the Latin America and Caribbean region. The database was created as a follow up to the report on 'Resource Efficiency in Latin America: Economics and Outlook' (UNEP 2011a), to establish a broader and deeper empirical basis upon which analyses specifically relating to primary material flows, and indicators of resource efficiency based on those flows, can be based.

The scope of this supplementary report on Material Flows is to establish national material flow accounts for many economies of the region based on the best available methodology (Eurostat, 2011). While for some countries such data already existed (see Section 8 of this report) this is the first time evidence for a large number of countries based on a coherent accounting framework is available, therefore allowing for comparison among countries. Beyond this, the report presents a very limited range of resource efficiency measures based on these material flows, notably material intensity (DMC/GDP) and per capita material flows, and provides some insight into the main drivers of material use. An analysis of energy use (as opposed to the tonnages of fuels from which energy is typically derived) was not in the scope of this report and information can be found in various reports of the International Energy Agency. Broader analysis of the political context is contained in the original 'Resource Efficiency in Latin America: Economics and Outlook' report and was also not within scope for this report, despite the considerable economic, social and environmental impacts of extractive, export-oriented industries that characterise some of Latin America's economic base. Detailed analysis of specific economic models for individual countries is also outside of the scope of the current report.

The database was designed to be consistent with the boundaries of what is considered as primary materials for material flows accounting by the statistical office of the European Union (Eurostat 2011) and so this report restricts itself to analyses based on primary flows of materials which can be categorized as biomass, construction minerals, fossil fuels, metal ores, and industrial minerals. It does not deal with issues relating to those primary resources which fall outside of these categories, most notably water and land, nor does it deal explicitly with emissions, all of which have been covered to varying degrees in above mentioned resource efficiency report (focused on Chile, Mexico and the Mercosur countries) (UNEP 2011a).

The rate at which humanity consumes primary materials has been rapidly escalating since the industrial revolution and especially since the rise of new, material and energy intensive lifestyles and mass consumerism in the middle of the 20th century. Until recently, growth in resources use, and especially that fraction of it involved in global trade, was dominated by demand from high-income OECD countries. This pattern is changing, with global materials consumption now driven by demand from populous developing countries which are undergoing rapid urbanization and industrialization. Much of this new dynamic is driven by countries in the Asia-Pacific region (UNEP 2011b), however the same industrial transition is also evident in Latin America. Furthermore, even though global demand for natural resources is largely driven by growth outside of Latin America, the increased globalization of trade means that supply pressures are transferred internationally. While Latin America has long been a source of raw materials for other regions, the region now finds itself incurring the extractive pressures to supply raw materials for new demand centres, while trying at the same time to meet the demands of its own industrial transition.

To put the resource use patterns and trajectories observed for the region into a broader context, comparisons are generally made with world trends overall, and also some more specific comparisons are made with the Asia-Pacific region. The latter was chosen for comparison both because it has recently had a similar study on resource efficiency completed for it, and because it is the region which has driven much of the recent increase in demand for many of Latin America's primary products (UNEP 2011b).

Box 1. Database preparation methodology and sources

A detailed technical annex describing the methodology and all base data sources behind the construction of the new database upon which this report is based is available at www.csiro.au/LatinAmericaCaribbeanResourceFlows. Key points from that annex are summarized hereafter.

All major base data sets used are available from publicly accessible (although often not free) sources. These sources included (EIA 2011, FAO 2011a, FAO 2011b, FAO 2011c, FAO 2011d, IEA 2011a, IEA 2011b, IEA 2011c, IEA 2011d, UN Statistics Division 2011a, UN Statistics Division 2011b, USGS 2011). A number of smaller countries in the region were excluded from the database, due to issues with base data availability, consistency, and reliability. The 22 nations included in the database are listed in Table 5.

The categories of materials covered are those considered primary materials in the material flows accounting framework described by the office of statistics of the European Union (Eurostat 2011), i.e. biomass, construction minerals, fossil fuels, metal ores, and industrial minerals. Importantly, while the base data sets used were generally of high quality, they were often specified in terms of a material of value extracted, while the new database requires that they be specified on an 'as extracted' or similar basis. For example, (USGS 2011) generally gives data on mining production in terms of contained metal, whereas mine production in the new database needs to be specified in terms of ore extracted. This requires, as a minimum, the application of different assumed ore grades for different metals. For some sub-categories of materials there was little or no direct base data of any sort, so tonnages had to be determined via modelling and inference. A notable example of this is the modelling of grazed biomass.

The methodology used to compile the database complied as nearly as practicable to the guidelines set out by Eurostat (2011), however where there have been significant departures from these guidelines the rationale behind them and their implementation is described in detail in www.csiro.au/LatinAmericaCaribbeanResourceFlows.

The frequent lack of data on materials extraction which would enable direct calculation of extractive loads on the environment encountered in creating this database, emphasizes the importance of recommendation four of the report on Resource Efficiency for Latin America (UNEP 2011a) regarding the need to improve the availability of environmental statistics.

3.Material use patterns and material efficiency in Latin America

Figure 1 shows domestic materials consumption (DMC) for Latin America increasing from 2.1 billion tonnes to 7.7 billion tonnes between 1970 and 2008, a compounding growth rate of 3.4% p.a. This compares to a growth rate for the rest of the world over the same period of 2.7%, so the region's share of global DMC increased from 8.5% to 10.9% over the period. As the region still constitutes a fairly small portion of the global total, we will see in other graphs below that there is little difference between values for the rest of the world (i.e. excluding Latin America), and World. The Latin America region's relatively low share of global DMC also implies that while changes in local demand will not have much effect on global averages, modest changes in material flows in the major global demand centres, if transferred via trade, can have quite large effects on the region. Some indication of this can be seen in Figure 1. The obvious move to a higher growth regime for the rest of the world from 2002 was reflected in a similar change in the growth regime within the region. Subdividing the full period into pre-2002 and post-2002 periods, we find that growth in DMC within the region increased very strongly, from 3.1% p.a. compounding in the early period, to 4.9% in the later period. This latter higher growth regime was in large part driven by external demand, and is discussed later. For a broad and qualitative discussion of historical drivers of environmental pressures in general for Latin America, the reader is referred to UNEP (2011a), while specific drivers of DMC as analysed through an IPAT[1] framework are dealt with below, in section 6 of this report.

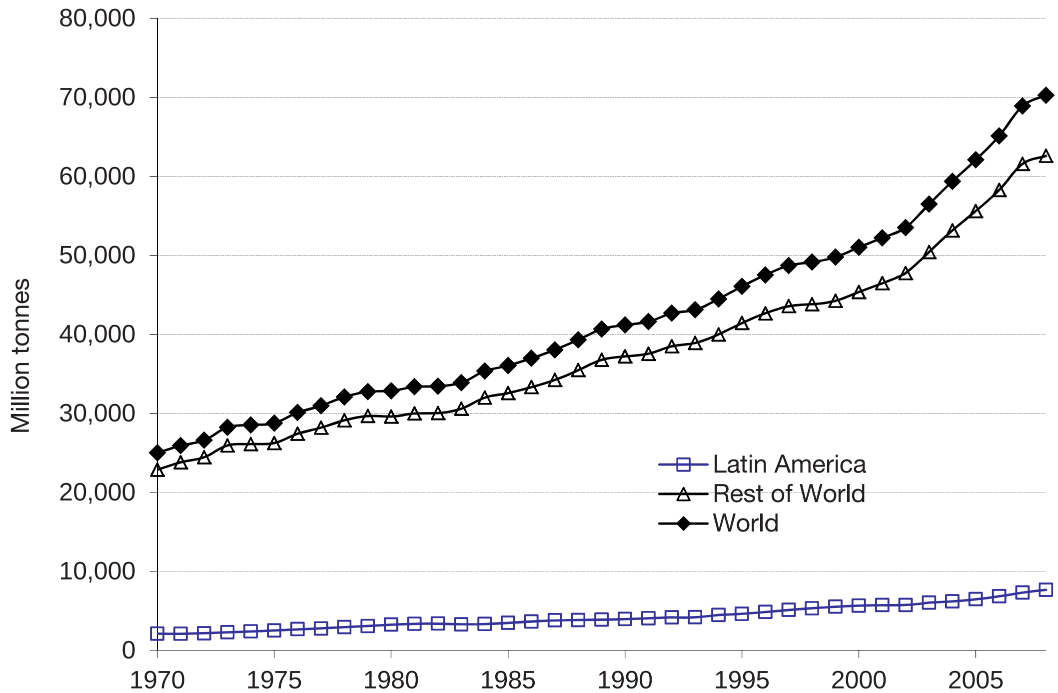

Figure 1 Domestic Materials Consumption for Latin America, Rest of the World, and World, for the years 1970 to 2008

1 The equation developed by Ehrlich and Holdren in the early 1970s that states that an Environmental impact (I) is driven by Population (P), Affluence (A) and Technology (T).

In Figure 2 we see that DMC per capita for Latin America began the period 1970 to 2008 slightly higher than World averages, and since that time grew at 1.5% p.a. compounding, diverging further from world trends so that by 2008 it stood at 13.6 tonnes per capita, over 30% higher than for the rest of the world. Importantly, even when adjusted to a per capita basis, the acceleration in growth in DMC from 2002 is seen to mirror and slightly amplify the trend for the rest of the world. Another noteworthy feature of Figure 2 is that there is little impact evident in the region from the onset of the Global Financial Crisis, in contrast to the pause in the rest of the world's materials consumption.

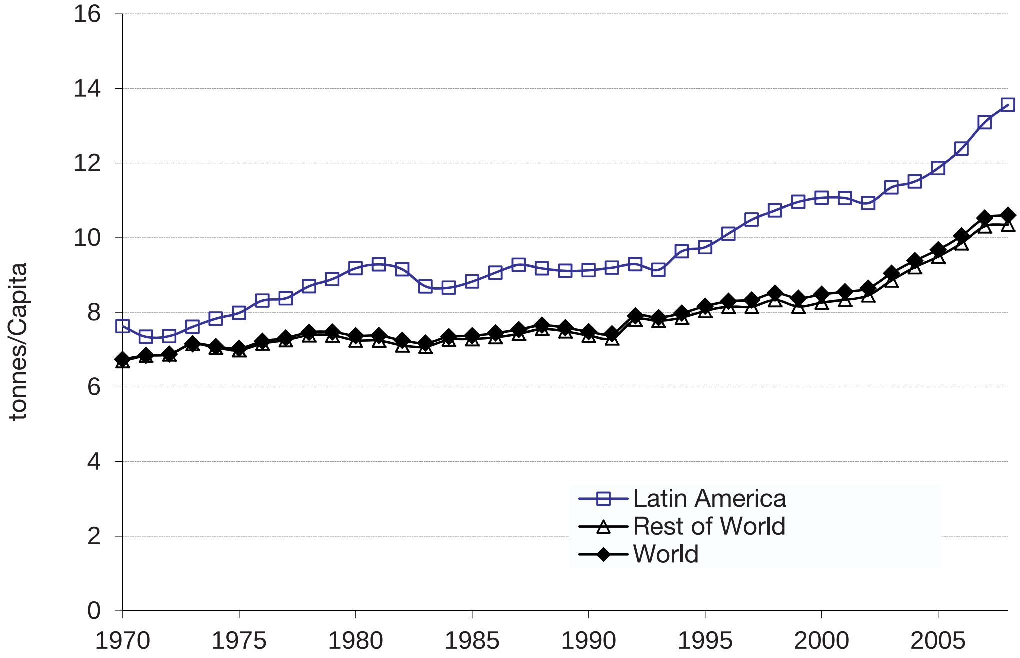

Figure 2 Domestic materials consumption per capita for Latin America, Rest of the World, and World, for the years 1970 to 2008

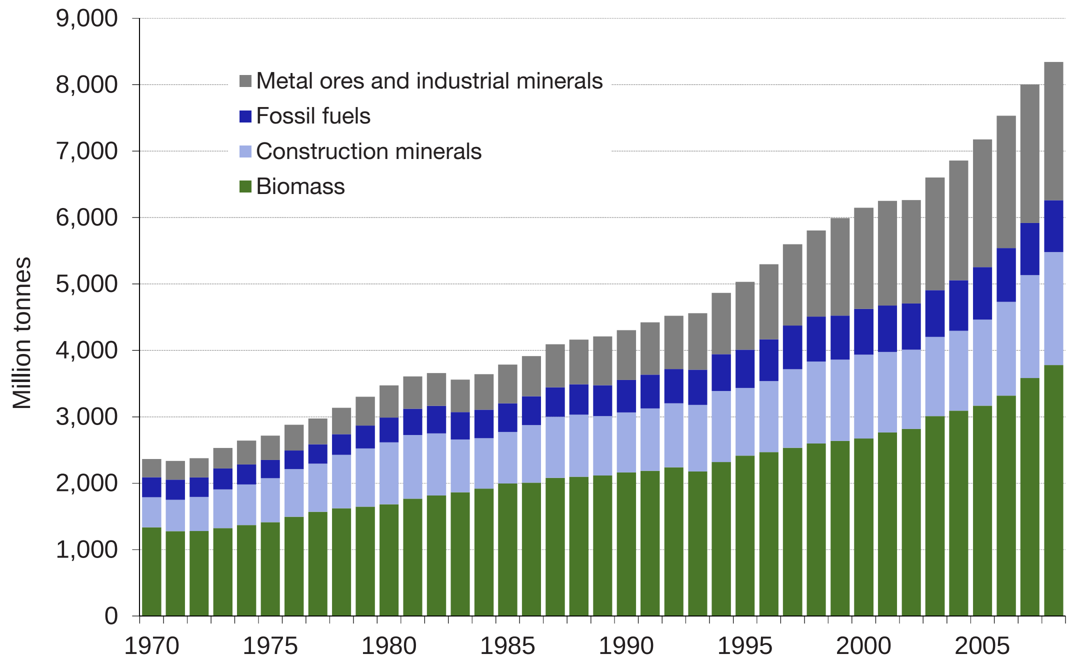

Figure 3 Domestic extraction in Latin America by major category of material for the years 1970 to 2008

Figure 3 shows how domestic extraction (DE) of four major categories of primary materials has changed over time in Latin America. Extraction of all categories increased strongly over the period 1970 to 2008, with extraction of biomass compounding at 2.0% p.a., fossil fuels 2.5% p.a., metal ores and industrial minerals 5.5% p.a., and construction minerals by 3.5% p.a.

The differential rates of growth between different categories of materials led to a considerable shift in the material basis of societies within the region, although this shift has been considerably less pronounced than that seen in the Asia-Pacific region, the other region which has been subject to a similar study using identical methods (UNEP 2013), and one which is also dominated by newly industrializing countries. This difference between the two regions is largely accounted for by much slower relative growth in construction minerals in Latin America, and a much faster growth in total biomass production. This latter is largely a result of developments in Brazil in particular, where biomass is actually serving as a significant substitute for liquid transport fuels usually supplied by fossil fuels. This is discussed in more detail below, however the end result is that the region has an apparent pattern of resources use which underplays the degree to which the agrarian to industrial transition has in fact already played out. The speed of infrastructure development in Latin America has also been comparatively slow, while economic growth in some countries has been dominated by the export-oriented primary resource sectors of mining, energy and agriculture.

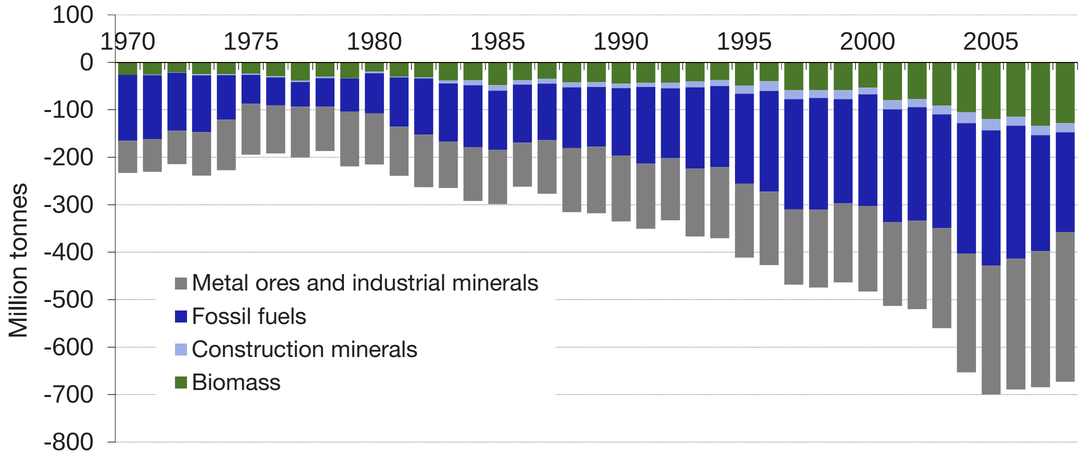

Figure 4 Physical Trade Balance for Latin America by major category of material for the years 1970 to 2008

Figure 4 shows that Latin America was a net exporter of all four major commodity categories for almost all years between 1970 and 2008. There was relatively consistent growth in net exports of both biomass and metal ores and industrial minerals across the period. Growth in exports of fossil fuels grew consistently from the late 1970s until 2005, but appears to have contracted since. Total net exports grew more than threefold between 1970 and 2008, and this figure almost certainly understates the degree to which extractive pressures in the region have been driven by external demand growth. This is because the two categories in which the most rapid growth has occurred, biomass and metal ores and industrial minerals, are also the categories in which the extracted raw materials undergo the highest degree of concentration prior to being traded as commodities. Non-ferrous metals for example are typically traded after first being upgraded to concentrates, or crude metal ingots, rather than in the form of ore. Table 1 gives an indication of the range of concentration, which typically takes place between the raw material as first extracted and the traded primary commodity.

	Potential for concentration in traded commodities	Indicative ratio ranges of extracted raw material to traded commodity
Construction minerals	Low, especially for the volumetrically dominant category of construction aggregates	1–2 : 1
Fossil fuels	Low (for traded fuels, excludes consideration of energy embodied in commodities such as aluminium)	1–2 : 1 for fossil fuels traded as fuels or refinery feed stocks (excludes non-conventional petroleum)
Biomass	Low to high. Exported crops are generally low, while animal products typically embody plant biomass one to two orders of magnitude higher	1–3 : 1 for crops and wood. 3–50 : 1 for animal products excluding whole milk
Metal ores	Medium to extremely high	1-3 : 1 for ferrous metals, 3-300 : 1 for base metals, 10-2,500 : 1 for uranium, 5,000-2,000,000 : 1 for precious metals

Table 1 Indicative degrees of concentration between raw material as extracted and traded primary commodities (after UNEP 2013)

The growth in net exports for Latin America shown in Figure 4 provides another interesting contrast with the pattern observed in the Asia-Pacific region (UNEP 2013), where there has been very strong growth in net imports, and growth has been particularly strong in recent times for metal ores and industrial minerals. This indicates a functional complementarity between the two regions, with Latin America boosting its role as a source region of materials as net imports of materials increase rapidly in the Asia-Pacific. Latin America appears to be increasing its function as an extended hinterland for industrialization taking place elsewhere in the world, consistent with the process of 'primarization' of the region's economy, as referred to in the Resource Efficiency report for Latin America (UNEP 2011a). This economic pattern means that the environmental and social impacts of material extraction occur in the region whilst the materials are consumed elsewhere. In such cases where primary materials are exported without adding value to the primary resource, the economic benefit for the region is small especially at the community level. (Please see section eight of this report for further detail.) Importantly, the extractive pressure incurred by serving as a supplier to other regions is occurring in addition to increasing demand from ongoing local industrialization.

Figure 5 shows DMC disaggregated by the four material categories. DMC is calculated from the sum of DE domestic extraction and physical trade balance (PTB). As the PTB for Latin America is small compared to DE, this figure closely resembles Figure 3, however the effects of trade concentration can strongly underplay the effective economic difference between the two measures. To illustrate this dynamic, we consider a tonne of metal ore consisting of 1% metal and 99% waste rock. If this ore undergoes processing into a crude metal ingot prior to export, the original tonne will be credited to the extracting country's DE account, while only the 1% contained metal will be subtracted from its DMC account. Even though all the material of value has passed in crude form to another country, the country where it was extracted will be deemed to have 'consumed' 990kg of metal ores and industrial minerals, while the country which received the metal will have consumed only 10kg of metal ores and industrial minerals. As with countries, regions which receive much of their resource requirements via imports will thus generally have a DMC account which is low, compared to the extractive pressure their economies ultimately exert, but displace the natural resource pressure to other jurisdictions. The opposite is true for those regions which disproportionately supply raw materials.

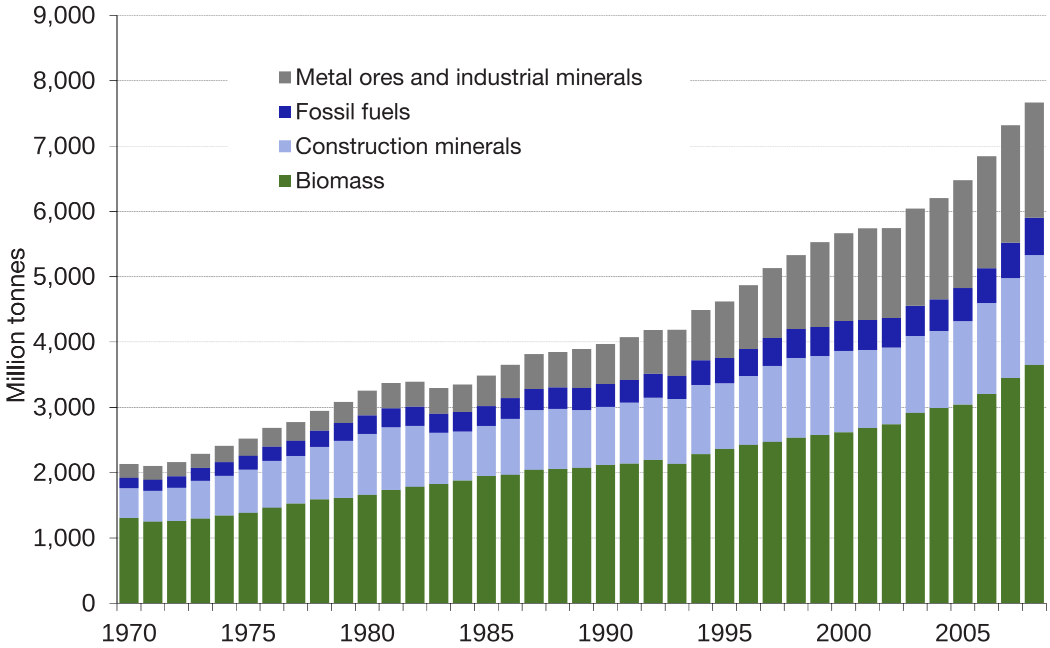

Figure 5 Domestic material consumption in Latin America by major category of material for the years 1970 to 2008

In Figure 6 we give side by side snapshots of the material bases for the Latin American economies for 1970 and 2008, to show the degree to which the transition from biomass-based to mineral-based societies has taken place. DMC is the measure used here, accounting for the slight change in percentages for each material category from the discussion of Figure 3, which used DE. Nearly all of the contraction in the share of biomass in the total is accounted for by the very rapid growth in metal ores and industrial minerals, with shares for construction minerals and fossil fuels remaining roughly constant.

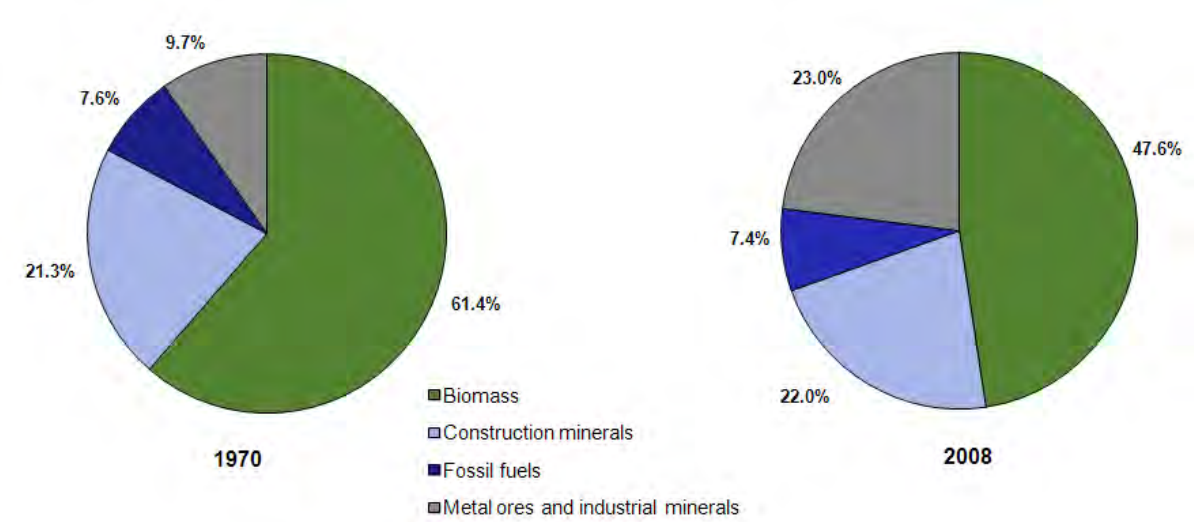

Figure 6 Change in relative shares of domestic material consumption in Latin America, by major materials categories between 1970 and 2008

Table 2 provides detail on the changes in relative shares of different categories of materials at the eleven category level at five points in time from 1970 to 2008, while Table 3 provides changes in total tonnages, and hence demonstrates the large underlying growth in materials consumption which has taken place in almost all categories over the period.

	1970	1980	1990	2000	2008
Biomass (% of total DMC)	61%	51%	53%	46%	48%
Primary crops	21%	18%	19%	16%	17%
Crop residues	17%	14%	15%	13%	15%
Grazed biomass	17%	14%	14%	13%	12%
Wood	7%	5%	5%	5%	4%
Fossil fuels (% of total DMC)	8%	9%	9%	8%	7%
Coal	0.5%	0.7%	0.9%	0.8%	0.8%
Petroleum products	6.0%	6.8%	6.2%	5.5%	4.8%
Natural gas	1.1%	1.3%	1.7%	1.8%	1.9%
Metals and industrial minerals (% of total DMC)	10%	12%	15%	24%	23%
Iron ores, concentrates, iron and steel	1.2%	2.0%	1.7%	1.4%	1.4%
Non-ferrous metal ores, concentrates, metals	8%	9%	13%	21%	21%
Industrial minerals	0.5%	0.6%	0.6%	0.9%	0.7%
Construction minerals (% of total DMC)	21%	29%	22%	22%	22%

Table 2 Share changes in domestic materials consumption in Latin America, disaggregated by eleven material categories, over the period 1970 to 2008

In Table 2 we see that crops and crop residues have contracted much more slowly in share terms than wood and grazed biomass, and for the most recent period began to increase their share of the total. Table 3 shows tonnages in all biomass categories at least doubled, with crop related extraction tripling. While an increase in the relative share of crops to grazed biomass could indicate a food system which is becoming increasingly efficient in the way it obtains dietary calories, avoiding the losses inherent in most animal production systems, this is not likely to be the explanation here. The increases in crop production are dominated by the contribution of Brazil, and are largely the result of a massive expansion of sugar cultivation in that country, much of which is used for ethanol biofuels production.

The fossil fuel mix over the period remained dominated by petroleum, although both coal and natural gas increased in share of all DMC, and relative to petroleum. Natural gas consumption grew fastest, at 4.9% p.a. compounding from 1970 to 2008, although this was off a low base so it still constituted less than 40% of petroleum consumption, by tonnage, in 2008.

The massive growth in metal ores and industrial minerals share over the period was totally dominated by non-ferrous metals, which grew at a compounding rate of 6.1% p.a. over the period 1970 to 2008.

	1970	1990	2008	2008/1970
Biomass (Mt)	1,308	2,118	3,650	2.8
Primary crops	440	754	1,305	3.0
Crop residues	364	595	1,152	3.2
Grazed biomass	359	571	901	2.5
Wood	145	198	293	2.0
Fossil fuels (Mt)	162	348	571	3.5
Coal	11	37	59	5.2
Petroleum products	128	246	370	2.9
Natural gas	23	66	142	6.2
Metals and industrial minerals (Mt)	207	612	1,764	8.5
Iron ores, concentrates, iron and steel	25	68	105	4.2
Non-ferrous metal ores, concentrates, metals	170	518	1,607	9.5
Industrial minerals	12	26	52	4.4
Construction minerals (Mt)	455	893	1,683	3.7
Total	2,131	3,970	7,668	3.6

Table 3 Total changes in domestic materials consumption in Latin America, disaggregated by eleven material categories, over the period 1970 to 2008

The share of construction minerals in the overall materials mix for Latin America, as reflected in Table 2, has remained remarkably constant over time, usually between 20 and 22%, except for a brief period around 1980 when it rose to nearly 30%. This profile suggests an incremental build-up of infrastructure over time, roughly proportional to the growth of the underlying physical economy. This contrasts markedly with the regional trajectory of the Asia-Pacific region as reported by UNEP (2013), where construction minerals in 1970 accounted for 23% of DMC, and increased for each decade after that, so that by 2008 they accounted for about half of total material use. This further indicates that the two regions appear to be following very different development paths. In making such a comparison, it should be kept in mind that there is great diversity between individual countries in Latin America, whereas the pattern of material flows for the Asia-Pacific region has in recent years come to be dominated by the development of China in particular, which has exhibited extremely dynamic growth even compared against other countries within its region.

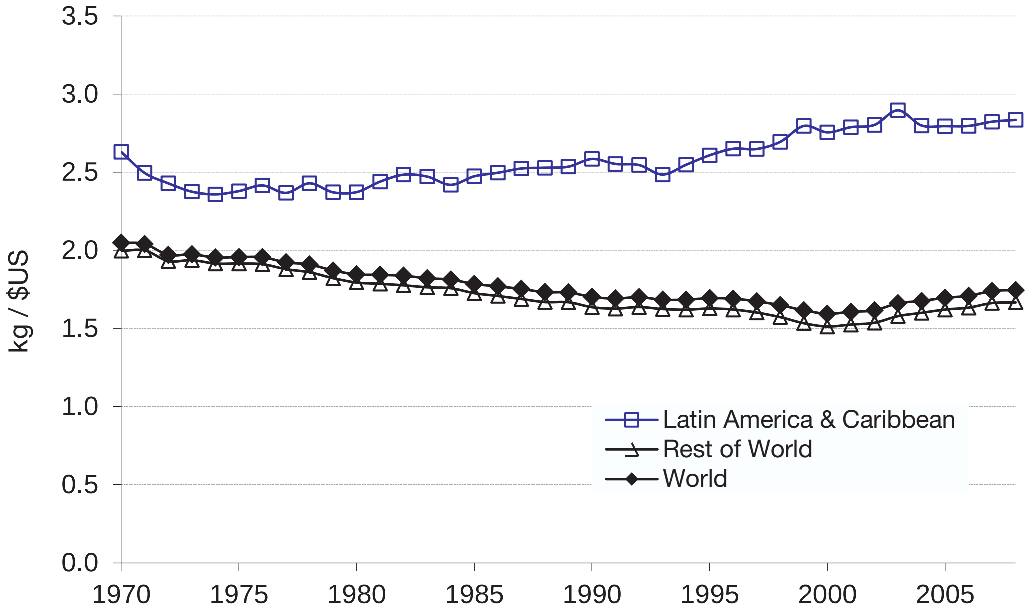

Figure 7 Domestic materials consumption per $US of GDP (exchange rate based, constant year 2000) for Latin America, Rest of the World, and World, for the years 1970 to 2008

Figure 7 shows the trend in materials intensity (MI) for Latin America. This is an indicator of the efficiency with which an economy is able to convert materials into GDP, i.e. the lower the MI, the more efficient an economy is at doing more (generating income) with less (consumption of materials and generation of associated waste products and emissions).

Between 1970 and the early 1990s, the region's MI remained roughly stable, at a time when world MI was steadily improving (i.e. decreasing). The region's MI then began a steady if modest increase from 1993 on, while world MI continued to decrease until 2000, before a period of steady increases took hold at the global level as well, driven by a dramatic expansion in some high MI newly industrializing countries in the Asia-Pacific region. The divergent trends between the world and Latin America over most of the period studied meant that by 2008, Latin America consumed 2.84kg of materials per $US of GDP created, 70% more than the 1.67kg per $US average for the rest of the world. In 1970, the difference in MI was less than 32%.

If reducing environmental impacts while maintaining economic growth is a policy goal, then this deteriorating trend in MI for the region is exactly contrary to what is required. If the current trend continues, environmental pressures will grow at a faster rate than economic growth. Indeed, on current trends, even if economic growth were to stagnate, extractive pressures on the environment would continue to grow. This demonstrates that there is certainly no sign of even relative dematerialization taking place in the region if we use aggregate MI as the indicator, and that environmental Kuznets curves are certainly not operating if the environmental indicator of interest is extractive pressure. A range possible factors affecting the retardation of the appearance of environmental Kuznets curves and decoupling more generally, in the context of Latin America, were put forward in the UNEP´s report on resource efficiency for Latin America (UNEP 2011a).

It is sometimes the case that regional MI will increase even as the MI for most of that region's constituent countries decreases. This phenomenon can happen when the relative shares of production in a region are redistributed towards less efficient economies. This dynamic has been identified in the Asia-Pacific region (UNEP 2013), however this is not what we are seeing in Latin America. In the section dealing with the ten highest consumption countries below, it is apparent that MI is increasing for most individual countries in the region as well. This implies that many of the initial actions required to even begin improving materials efficiency are yet to be taken by most individual governments in the region. Furthermore, achieving improvements in MI is also likely to be made harder by the region's general orientation towards high and increasing resources exports, due to the value added to primary commodities being relatively low compared to manufactured goods (and services), per unit of weight. This is again consistent with the process of 'primarization' taking place in the region, referred to in the UNEP report on resource efficiency for Latin America (UNEP 2011a). This becomes particularly apparent in the detailed discussion of the ten highest total DMC countries, presented in section 4, where the greatest increases in MI tend to be for countries that have boosted metal ores and industrial minerals exports. From the same set of countries we also see that MI performance within the region varies widely, ranging in 2008 from 1.5 kg per US$ for Venezuela to 10.2 kg per US$ for Chile.

Credit: Fundación Albatros Media

4. Material use patterns and material efficiency for selected countries

In this section, material use patterns and material efficiency are reviewed for the ten countries having the highest total DMC in Latin America. These ten countries fit into two classes of the six type country classification set out by (Krausmann et al. 2008) and are used as guidance to a country's socio-metabolic profile[2] (see Table 4). The represented classifications include: low population density developing countries of the New World, and high population density developing countries.

	Industrialization	
	Industrialized countries	**Developing countries**
High population density	High-density industrial e.g. Japan	High-density developing Mexico, Guatemala, Ecuador
Low population density		
New World	Low-density industrial – New World e.g. Canada	Low-density developing – New World Argentina, Bolivia, Brazil, Chile, Colombia, Peru, Venezuela
Old World	Low-density industrial – Old World e.g. Finland	Low-density developing – Old World e.g. Mongolia

Note: Industrialized countries include OECD countries and transition markets; developing countries include developing and least developed countries based on the classification of UNSD (2006). Countries with a population density above 50 persons per km^2 are considered high density.

Table 4 Country classification system of Krausmann et al. (2008)

Figure 8 shows that no single country dominates the region's DMC, although the largest, Brazil, grew its share considerably from 29% in 1970 to 38% of the regional total by 2008. Brazil's share in 2008 was almost equalled by the total of the next three largest (37%), with the remaining 25% spread among 17 countries. There has been a redistribution of DMC away from the smallest countries, with the 12 countries included under 'Other' accounting for only 7% of the regional total in 2008, down from 17% in 1970. Among the large countries, Chile's share of DMC has grown at the fastest rate, while Argentina's contracted at the fastest rate, such that the relative shares of these two countries roughly reversed over the period, with Chile's increasing from 6% to 14%, while Argentina's declined from 15% to 8%. Note that while Argentina's ***relative*** share of the regional total declined quite rapidly, in absolute tonnage terms Argentina's DMC still increased by over 90%. Mexico's share remained fairly stable over the period, accounting for 15-19% of the regional total in every year. Of the two largest countries, one (Brazil) is a low population density developing country of the New World, while the other (Mexico) is in the high population density developing country category.

2 Social metabolism is analogous to the biological concept of metabolism. Like biological organisms, socio-economic systems depend on throughputs of materials and energy for their continued existence and growth. Much as different plants and animals occupying different biological niches have very different requirements for materials and energy (compare the nutritional requirements of a small bird and a large fish), the material and energy requirements of nations which occupy different niches in the global economy vary widely. A socio-metabolic profile refers to the size and make-up of the material and energy flows specific to a particular country.

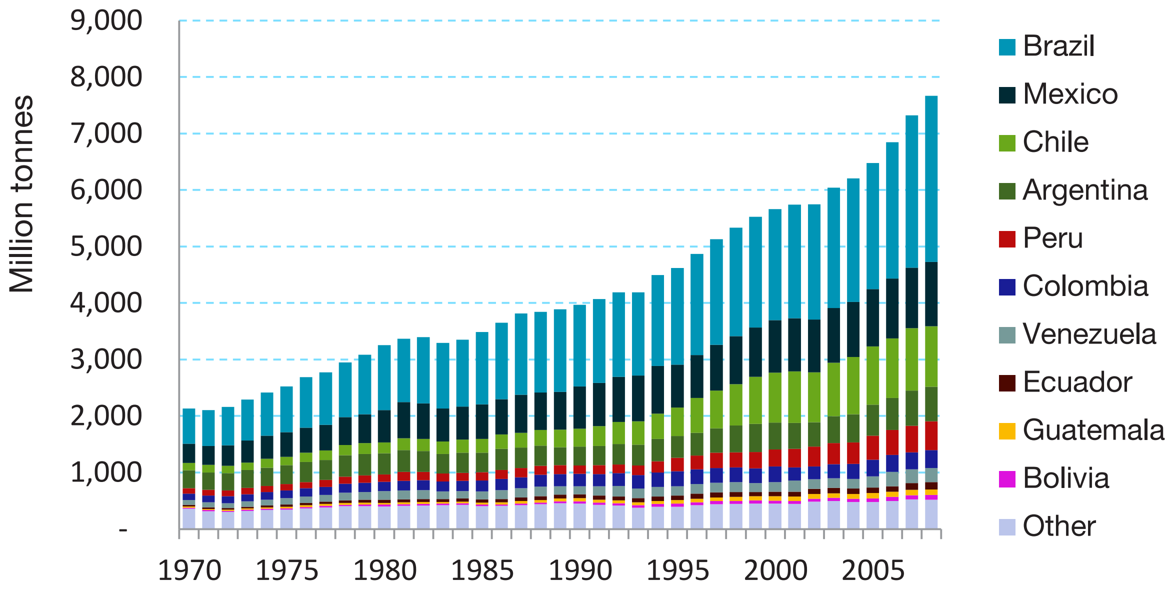

Figure 8 Domestic Material Consumption of the ten highest consumers of materials in Latin America in 2008 (NB: "Other" category includes other larger Latin America and Caribbean countries, see Table 5)

5 Focus countries

Some 22 countries included had sufficient data on material flows available to warrant their inclusion in the Latin America and Caribbean regional material flows database. These are grouped by sub-region in Table 5.

Sub-region	Countries
South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
Meso-America	Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
Caribbean	Cuba, Dominican Republic, Haiti, Jamaica, Trinidad and Tobago

Table 5 Countries included in the Latin America and Caribbean region material flows database

A more detailed analysis for ten 'focus countries' is provided hereafter, to give greater insight into the individual variations in the evolution of material flows over time seen between different countries in the region. The focus countries were selected purely on the grounds of the magnitude of their total material flows, i.e. they were the ten countries with the highest total DMC in the Latin America (and indeed the Latin America and Caribbean) region in 2008.

Credit: Fundación Albatros Media

5.1 Argentina

Argentina began the period 1970 to 2008 with a DMC per capita over 75% higher than the regional average, then began to converge with the regional average (Figure 9). The convergence of Argentina's DMC per capita towards the regional average was facilitated by it trending towards lower MI over most of the first three decades, such that in some years it came within 5% of the regional average. This trend in MI stagnated or even deteriorated from the late 1990s, however its MI is still amongst the most favourable in the region. The erratic path of DMC per capita reflects high volatility in the biomass component, and this volatility is even more apparent in the PTB, where biomass constitutes the majority of Argentina's net exports in all years. Proportionally, Argentina's net exports of biomass have grown much more rapidly than biomass DMC. This increasing emphasis on agricultural exports may explain why Argentina, despite having one of the highest levels of development in the region, has retained ratios between the different material categories more typical of a country which is at a very early stage of the agrarian to industrial transition. Between 1970 and 2008, biomass's share of total DMC only decreased from 66% to 62%.

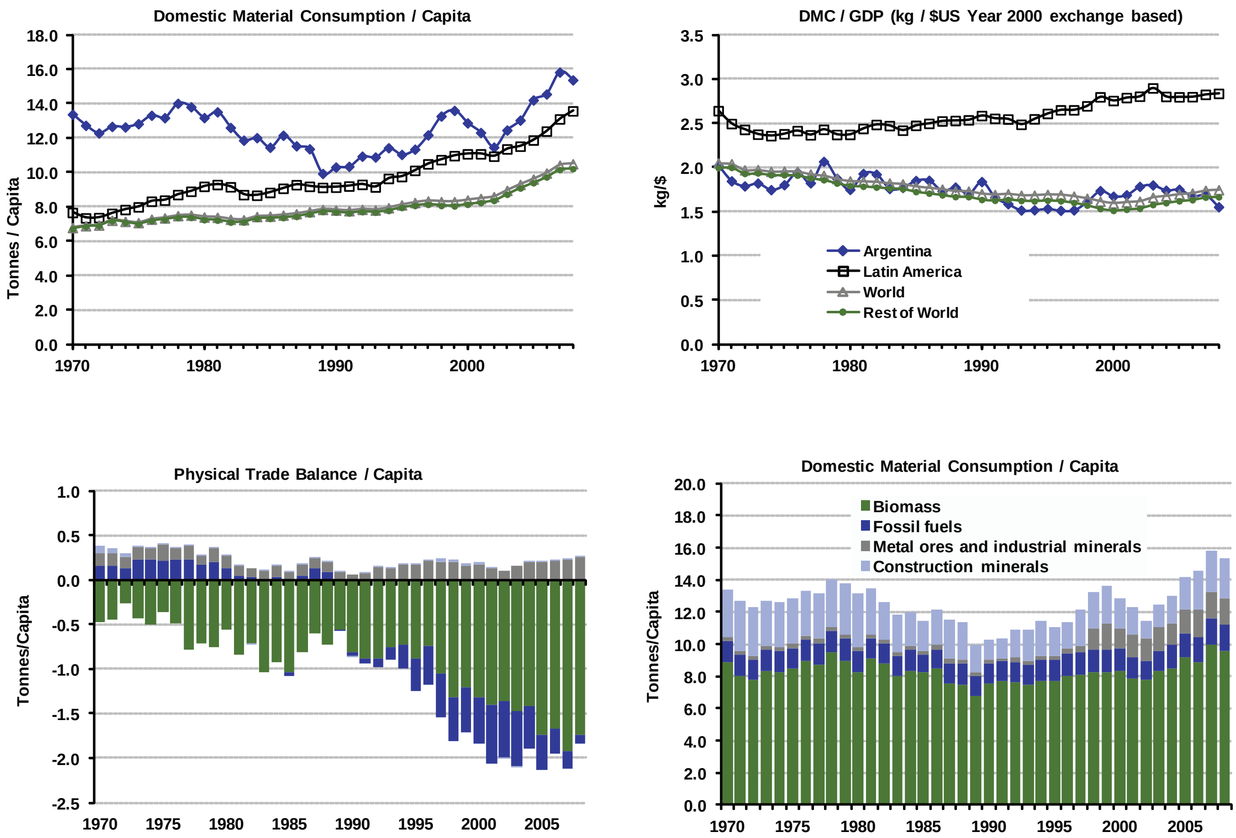

Figure 9 Summary panel of material flows and materials intensity for Argentina

The steep increase in metal ores and industrial minerals from 1998 onwards is largely accounted for by the commissioning of a giant copper-gold mine (Bajo de la Alumbrera). This event illustrates the significant effect of non-ferrous minerals extraction for export on material flows accounts. The several tens of millions of tonnes of ore extracted show up clearly in the DMC account, while the few hundred thousand tonnes of contained metals and/or metal concentrates exported barely affect the PTB account, where Argentina remains a net importer in the relevant category. Fossil fuels, mainly petroleum, became a significant component of Argentina's net exports from the early 1990s, then declined fairly rapidly from the mid 2000s.

5.2 Plurinational State of Bolivia

In 1970, Bolivia had a DMC of 4.6 tonnes per capita, well below both regional and world averages (Figure 10). This level of consumption grew at 1.7% p.a. compounding over the full study period, to reach 8.7 tonnes per capita in 2008. This rate was higher than both the regional and the rest of the world's average rates, however by 2008 Bolivia still consumed around 15% less per capita than the rest of the world's average, and 36% less than the regional average. In the four-category breakout of DMC, the volatility of metal ores and industrial minerals over time is notable. The 11 category disaggregation (West 2012) shows that this volatility comes from DE of non-ferrous metals, with estimated extraction in 2008 finally exceeding a previous peak reached in 1995.

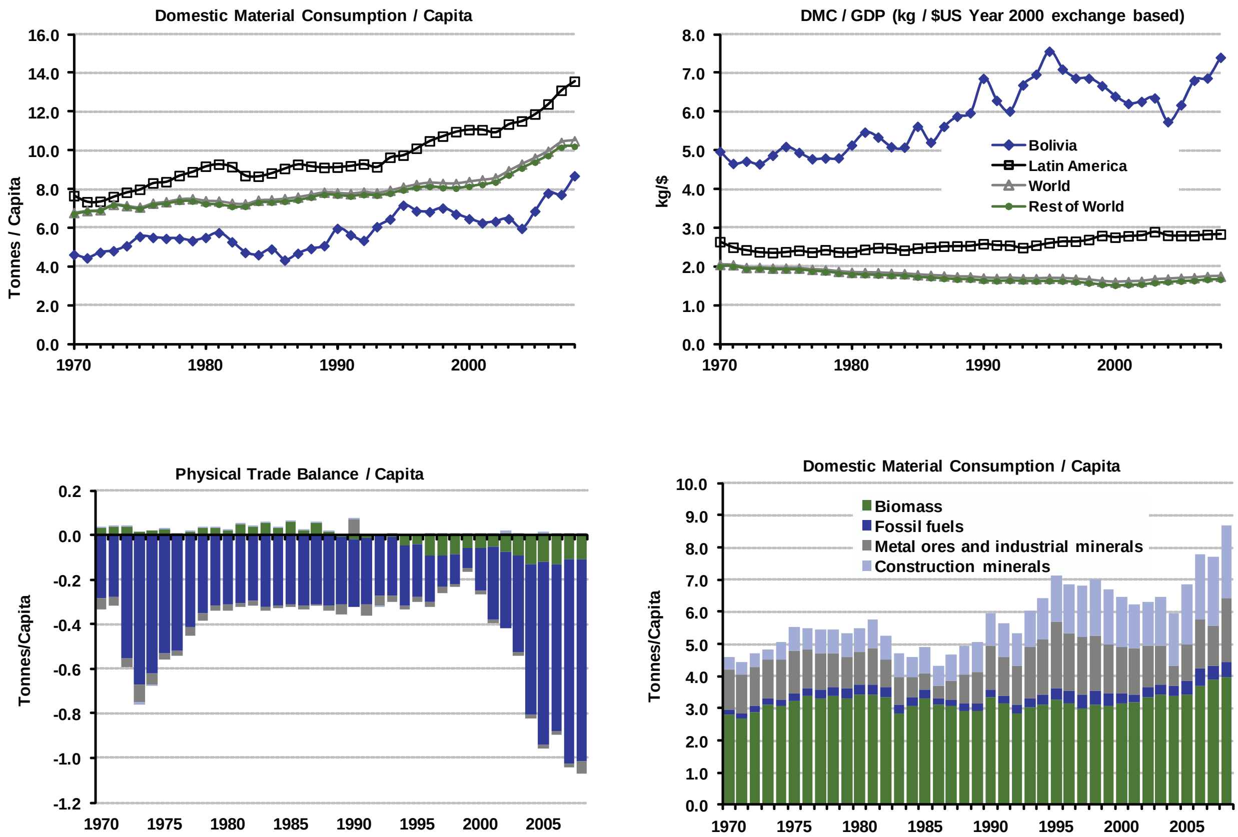

Figure 10 Summary panel of material flows and materials intensity for Bolivia

The share changes in DMC indicate that Bolivia's transition away from an agrarian society gathered momentum over the period, with biomass decreasing from 61% to 46% of total material use, and very strong and persistent growth in construction minerals, from 9% in 1970 to 26% by 2008, indicating growing investment in durable infrastructure. Unfortunately, the implied accumulation of infrastructure has not served to improve material intensity, which started the period high by regional and world standards at nearly 5 kg per $US, and increased to 7.4 kg per $US by 2008, over 160% higher than the regional average. The graphic on PTB shows that Bolivia is at least self-sufficient in net terms for all major materials groups, and that net exports are dominated by fossil fuels, overwhelmingly comprised of natural gas.

5.3 Brazil

Brazil's DMC in 1970 was 6.4 tonnes per capita, roughly equal to world averages. It then grew at a rate of 2.3% p.a. so that by 2008 it was around 50% higher than the world average, at 15.3 tonnes per capita (Figure 11). Unusually, some 70% of this increase can be attributed to biomass. This led to the share of biomass in Brazil's overall DMC remaining virtually unchanged between 1970 and 2008, at 70% of total material use. This does not indicate that Brazil's socio-metabolic transition has stalled, but rather stems from Brazil's production of sugar and derived biofuels on a scale large enough to supply a significant fraction of local transport demands, as well as enabling Brazil to become the world largest exporter of ethanol. An industrializing society usually becomes increasingly reliant on energy from fossil fuels to make up for shortfalls in the land's ability to supply sufficient biomass derived energy. Brazil's combination of vast area and suitable climate delivers such prodigious primary productive potential that this dynamic seems not to apply, or at least to have been delayed, locally. Of the four material categories, metal ores and industrial minerals grew the most in relative share, from 3.5% in 1970 to 6.4% in 2008.

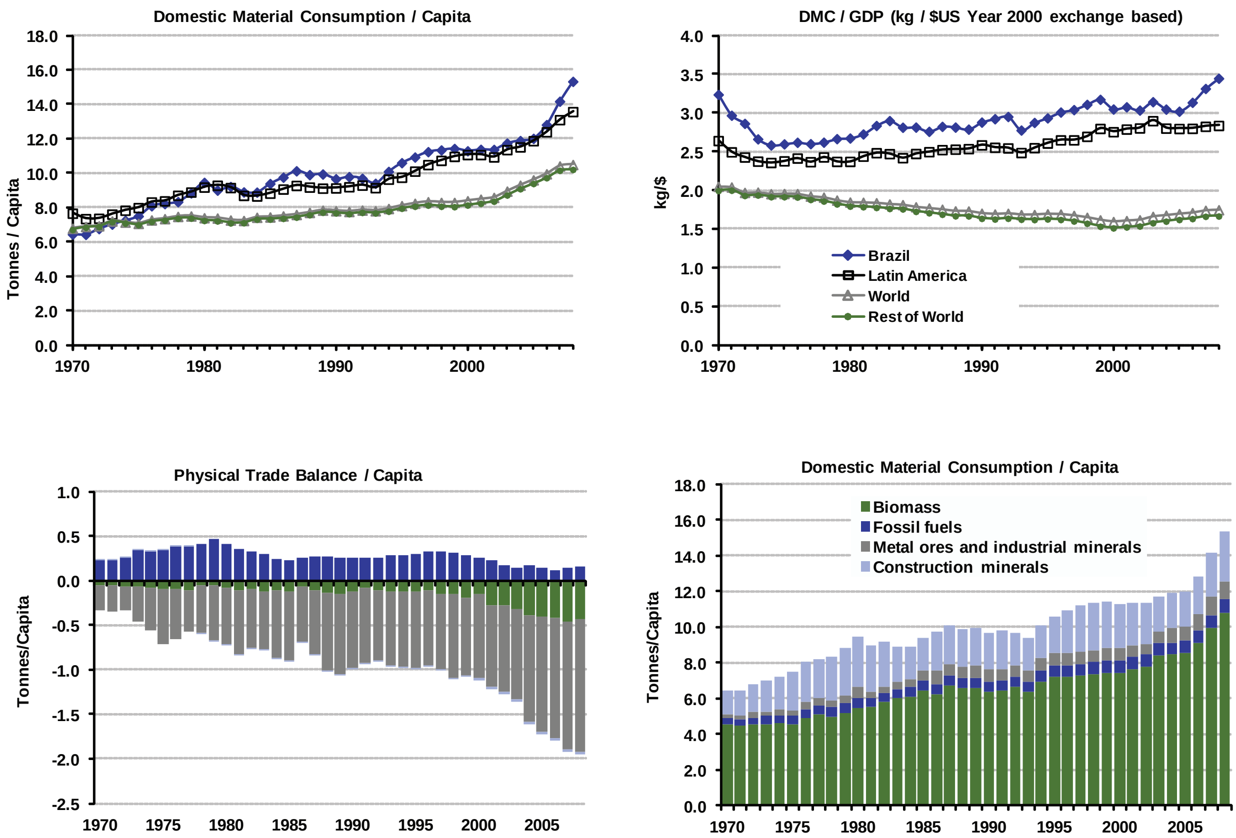

Figure 11 Summary panel of material flows and materials intensity for Brazil

The graphic on PTB shows Brazil's net exports being dominated by metal ores and industrial minerals in all years. The relatively high apparent ratio of net exports to DMC in this category forms an interesting contrast with that seen below for Chile and Peru, and can be explained by the dominance of iron ore in Brazil's export mix, which is subject to relatively low concentration prior to trade. Following a brief period of decrease from 1970 to 1974, MI trended higher through to 2008, leaving it with an MI consistently higher than the regional average for the entire period, and almost double the world average by 2008.

5.4 Chile

Chile's DMC per capita is by far the highest of the focus countries and one of the highest in the world. Having started from a base of 14.5 tonnes per capita in 1970, it grew by 4.0% p.a. compounding through to 2008, at which point it was 63.6 tonnes per capita, a factor of 4.7 and 6.2 times higher than the regional and world averages respectively (Figure 12). Almost all of this increase is accounted for by massive increases in DE of metal ores and industrial minerals for export, which in Chile is mainly copper. The change in relative shares of DMC between categories probably does not reveal much about the socio-metabolic transition in Chile, as copper extraction for export dominates from the beginning of the time series. Perhaps the main thing that can be surmised is that Chile is functioning largely as an extractive hinterland for other industrialized economies.

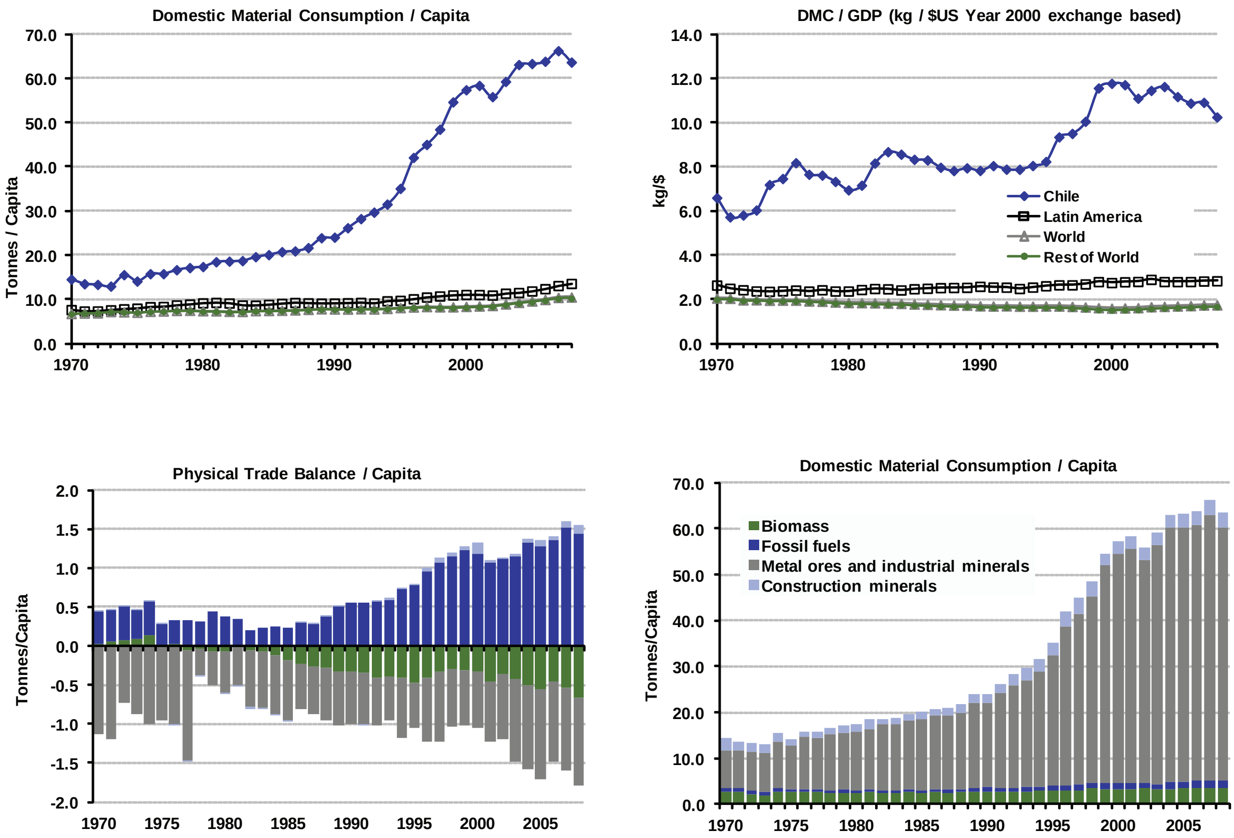

Figure 12 Summary panel of material flows and materials intensity for Chile

Chile's PTB pattern shows the country is becoming increasingly dependent on net imports of fossil fuels. Net exports are dominated by metal ores, although biomass exports have grown steadily since the 1980s. The extremely low ratio between PTB and DMC of metal ores is a result of the concentration which takes place between copper ore (typically < 1 % copper), and internationally traded metal/concentrate (20% - 100% copper)[3]. This also accounts for Chile having by far the highest MI of any of the focus countries analysed. The degree to which copper dominates Chile's material flows further suggest that the increasing MI trend for Chile over the long term results from a simple interaction between declining average ore grades, and cyclical variations in copper prices. These two factors should continue to dictate Chile's MI for the medium term at least.

3 The large dip in exports in 1978 is not matched by a corresponding decrease in DE. A possible explanation for that would be if Chile greatly increased conversion of concentrates to metals prior to export from that year.

5.5 Colombia

Colombia's DMC per capita started quite low, at 5.3 tonnes in 1970, and then grew at the slowest pace of all the focus countries, below 0.8% p.a., so that by 2008 it was only 69% of the world average and 52% of the regional average (Figure 13). When looked at by material category, there has been only modest variation over time, except for a pronounced slump in construction minerals consumption in the early 2000s. Biomass share of total DMC contracted marginally from 57% in 1970 to 53% in 2008, with small share decreases for both construction minerals and fossil fuels. DMC of metal ores grew strongly over the period, up from 3.2% in 1970 to 9.3% in 2008. The overall profile would be consistent with a relatively slow but ongoing industrialization.

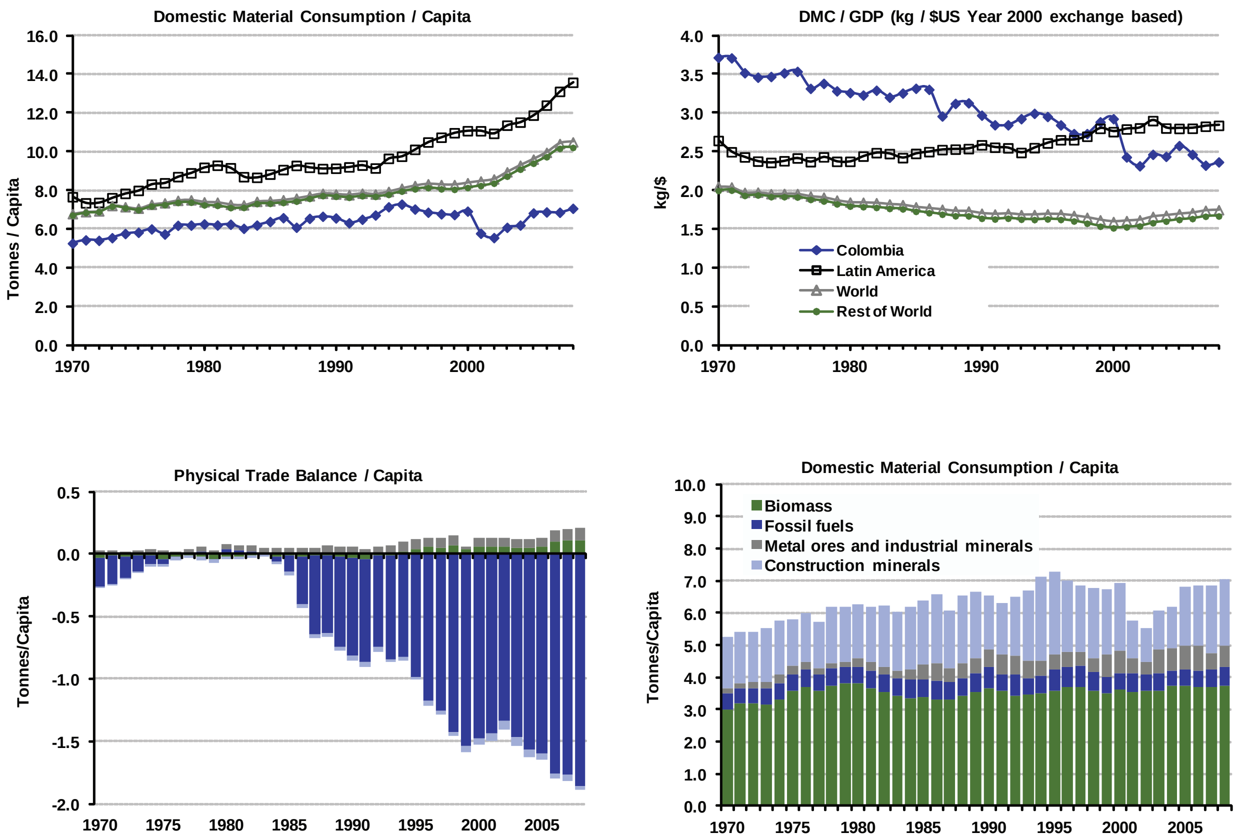

Figure 13 Summary panel of material flows and materials intensity for Colombia

The most salient feature of the PTB graphic is the rapid and ongoing growth in net exports of fossil fuels starting in the early 1980s. PTB is dominated by exports of fossil fuels, which are mainly of coal. Colombia remained a net exporter of petroleum in 2008, however at a rate only half that of its 1999 peak.

Colombia is the only focus country to have achieved a strong and sustained improvement in MI over the study period. In 1970, MI was over 40% higher than the regional average, at 3.7 kg per $US, but by 2008 this had declined to 2.4 kg per $US, 16% below the regional average. The mechanism by which Colombia has achieved this steady improvement is not obvious from the material flows accounts, but it would seem worthy of further investigation to see whether it holds clues as to how Colombia has achieved this environmentally desirable trajectory in a region were few others have.

5.6 Ecuador

Ecuador's DMC per capita started quite low, at 5.1 tonnes in 1970, and grew at 1.7% p.a. compounding, so that by 2008 it was 9.7 tonnes per capita, 95% of the world average, although still well below the regional average (Figure 14). Ecuador experienced a very strong shift in the relative shares of the main materials group over the study period, in indicating a large socio-metabolic transition. Where biomass constituted 79% of DMC in 1970, by 2008 it had decreased to only 43% (although tonnages of biomass DMC increased by 140%). The great bulk of the shift in shares is accounted for by a very rapid growth in construction minerals, which grew from 15% to 47% over the same period. Most of this shift in shares took place very rapidly, in the 1970s. In the most recent years, Ecuador's consumption of construction minerals per capita has actually been the highest of the focus countries in absolute tonnage terms, as well as in share. This should indicate that stocks of durable infrastructure are accumulating relatively rapidly in Ecuador. The share of fossil fuels grew from 4.5 % to 7.5%, while metal ores and industrial minerals grew from 1.2% to 1.8%, after peaking at 9.2% in 1991.

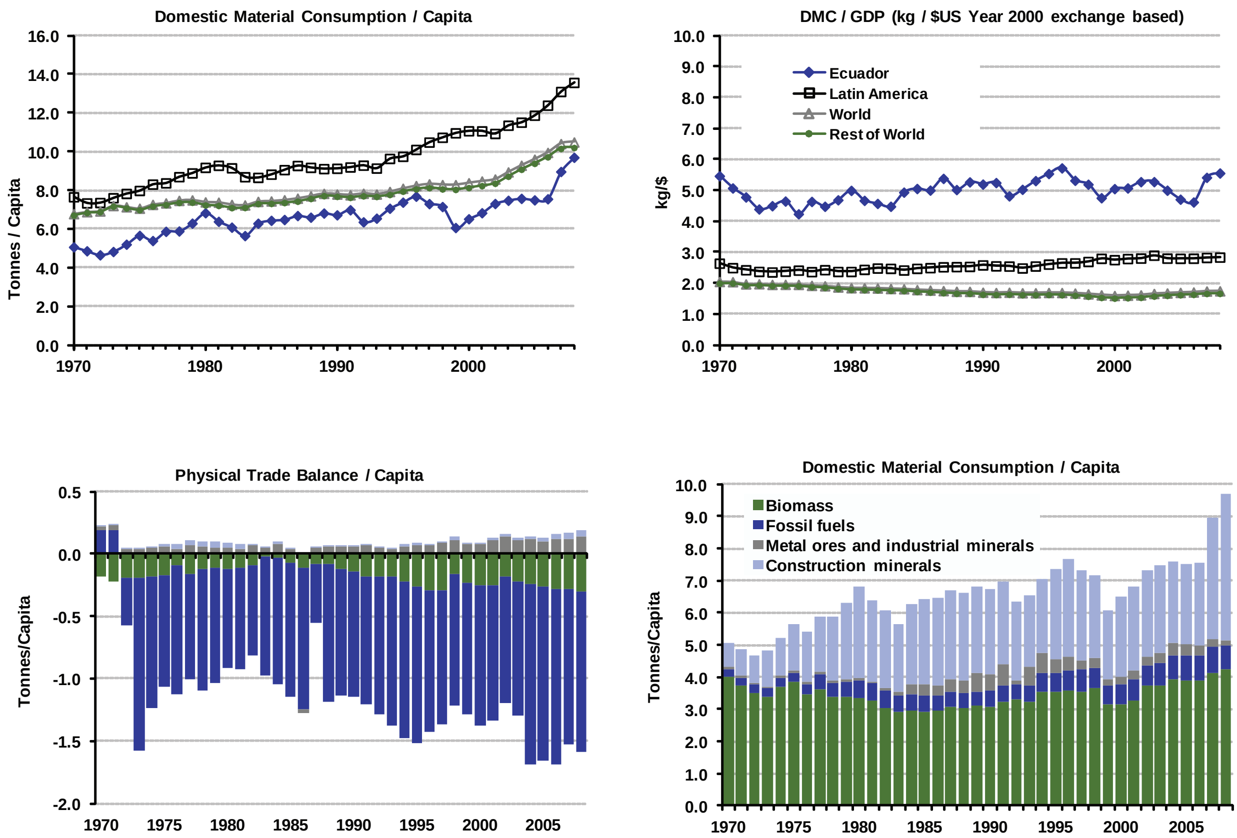

Figure 14 Summary panel of material flows and materials intensity for Ecuador

The very rapid transition from a net importer of fossil fuels to an exporter stands out in the PTB graphic. More detailed data shows that these exports are dominated by petroleum, which increased steadily over time, with a small decrease in the most recent years. Ecuador's MI is almost double the regional average, and exhibited no clear trend from 1970 to 2008. Values fluctuated between 4.2 and 5.7 kg per $US, with the period both starting and ending at the higher end of that range. It appears that wherever the construction minerals are being invested, they are not noticeably improving MI at the national level.

5.7 Guatemala

Guatemala had the lowest DMC per capita of the focus countries in 1970, at 3.68 tonnes or 48% of the regional average (Figure 15). This grew at 1.7% p.a. compounding, a rate slightly faster than the regional average so that by 2008 the figure was 6.86 tonnes per capita, representing 51% of the regional average. The share of biomass in total DMC dropped significantly, from 79% in 1970 to 58% in 2008, while construction materials' share grew strongly, from 15% to 31%. The share of fossil fuels dropped from 4.6% to 4.2%, although consumption of fossil fuels more than quadrupled on a per capita basis. DMC of metal ores increased most rapidly of all proportionally, by a factor of 21, with a share increase from 1.4% to 6.2%. The overall pattern suggests an ongoing steady transition to a more industrialized society.

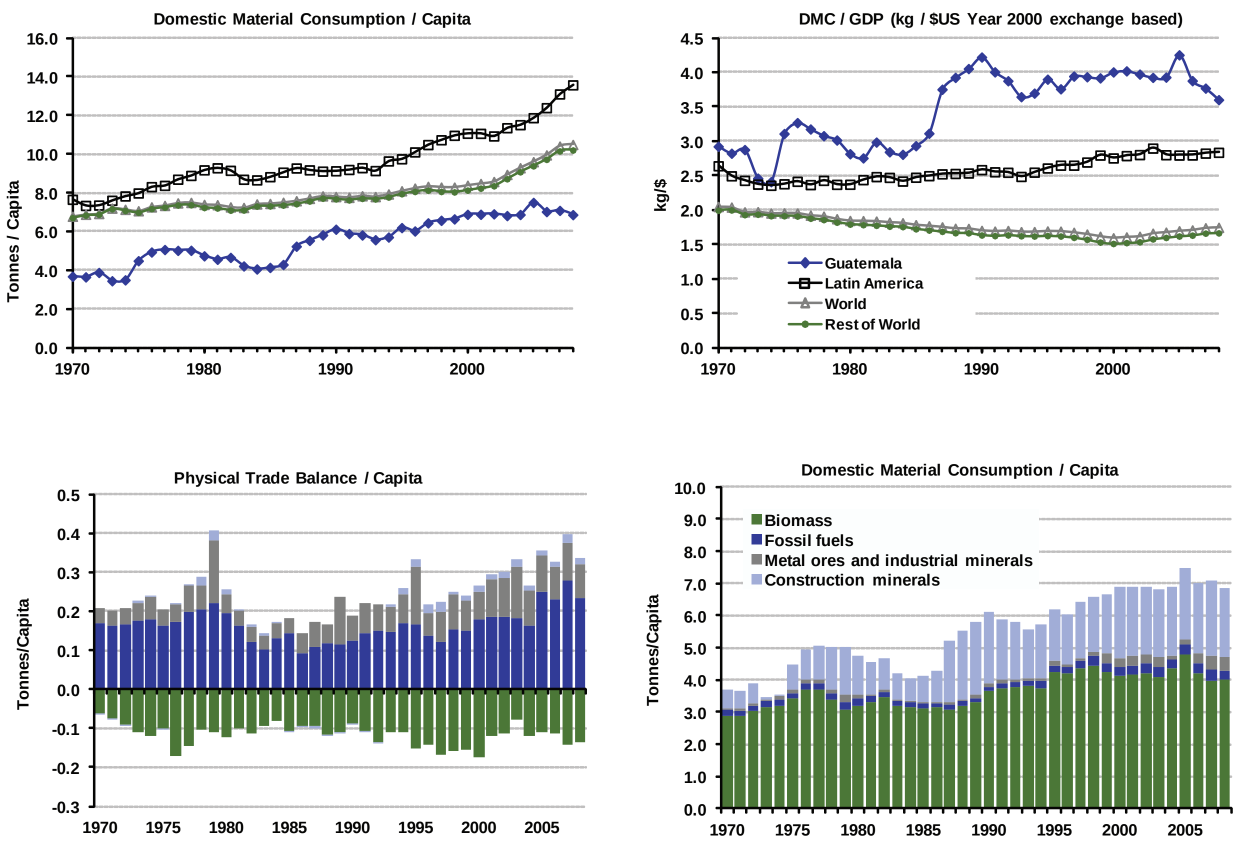

Figure 15 Summary panel of material flows and materials intensity for Guatemala

The graphic on PTB shows Guatemala to have been a net importer of all materials categories, for most years, except biomass, of which it has remained a consistent and growing net exporter. Guatemala is dependent on imports for most of its fossil fuel demand, which has historically been nearly all petroleum, although coal has made an increasing contribution in recent years. DE of petroleum peaked in 1998, when it constituted nearly half of petroleum DMC, however by 2008 DE covered less than a quarter of Guatemala's petroleum demand. The country is also highly dependent on imports for its metal requirements.

In 1970, Guatemala's MI was slightly higher than the regional average, at 2.9 kg per $US, however it tended to increase from that time, most notably from the mid 1980s to 1990, where it peaked at 4.2 kg per $US. It has since improved, decreasing to 3.6 kg per $US by 2008. As for Ecuador, any efficiency benefits which might accrue from the ongoing build-up of infrastructure have not as yet compensated for whatever countervailing dynamics are keeping MI high.

5.8 Mexico

Mexico´s DMC per capita value of 6.7 tonnes in 1970 was almost exactly equal to the world average, and its value of 10.5 tonnes in 2008 was similarly close (Figure 16). On two occasions, in the early 1980s and early 1990s, its DMC per capita rose to levels approximating regional averages, but subsequently returned to near the world trend. Changes in share between the individual components of DMC are indicative of an ongoing industrial transition, however starting the period at a much more advanced stage than the other Meso-American high population density developing country studied, Guatemala. Mexico's total per capita DMC and relative shares in 1970 were broadly similar to Guatemala's in 2008 (although Mexico's fossil fuel share was at all times more than double Guatemala's). Biomass decreased from 52% in 1970 to 35% in 2008, construction minerals increased from 28% to 40%, and fossil fuels increased from 11% to 14%, a share only exceeded in Venezuela. There was little change in metal ores share.

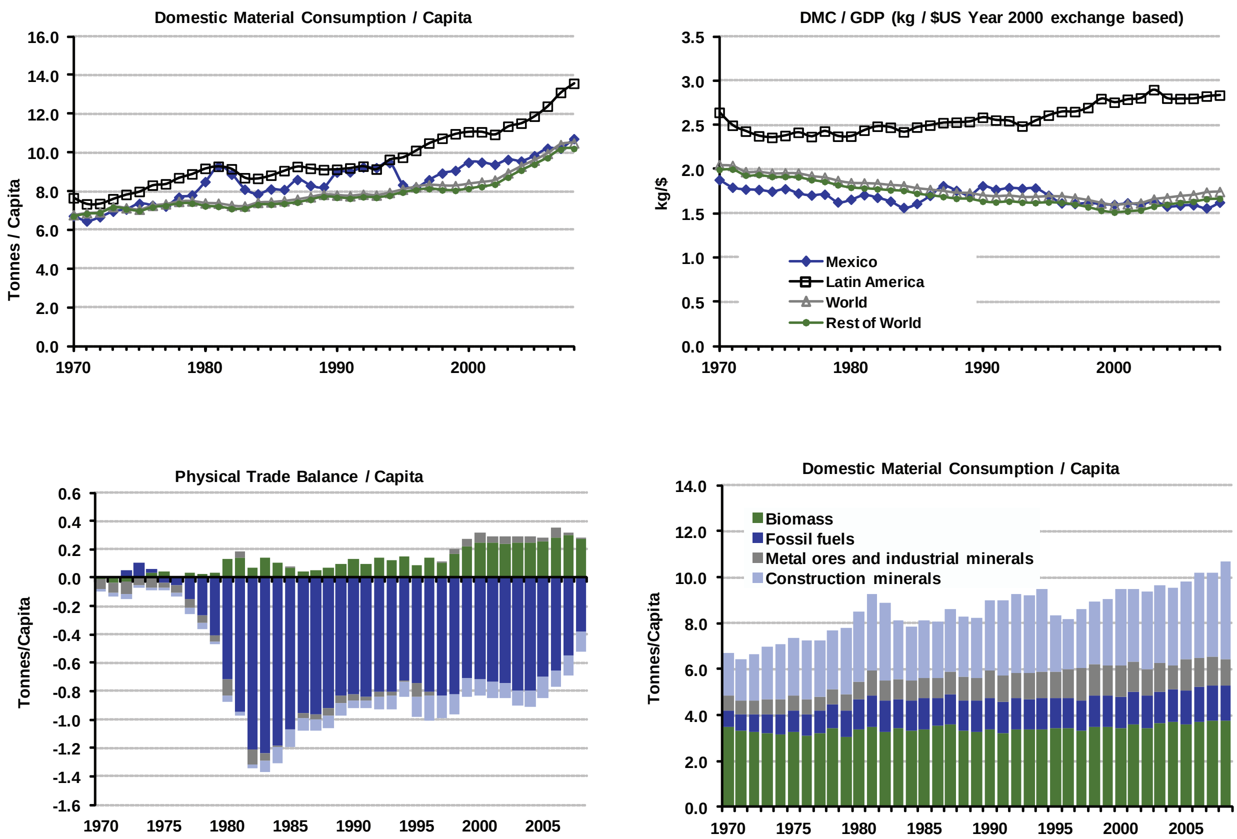

Figure 16 Summary panel of material flows and materials intensity for Mexico

The most salient feature of the graphic on PTB is the rapid transition of Mexico in the 1970s from a fossil fuel importer to a net exporter. The peak in net fossil fuel exports occurs within a decade of the beginning of this transition, and then gives way to an extended and continuing decline. An interesting feature is how the onset of substantial net imports of biomass coincided with this transition, however determining whether there was a causal link, such as Mexico realigning its economic activity away from agriculture to allow for expansion in the petroleum sector, is beyond the scope of this report. In 1970, Mexico's MI of 1.9 kg per $US was close to the world average. It then declined slightly to 1.6 kg $US by 2008, so diverging from the regional trend, and finished the period close to the world average again, over 40% below the regional average.

5.9 Peru

Peru's DMC per capita of 7.2 kg in 1970 was intermediate between world and regional averages. It grew by 2.4% p.a. compounding so that by 2008 it was 17.7 tonnes per capita, 31% higher than the regional and 74% higher than the rest of the world averages respectively (Figure 17). Nearly all (9.6 tonnes) of this growth is accounted for by metal ores and industrial minerals, with construction minerals adding 1.4 tonnes, while fossil fuels were stable and biomass actually decreased. Reference to the 11 category data in (West 2012) shows that over 99% of DMC in metal ores is accounted for by non-ferrous ores. The pattern of share changes in the four major material groups is reminiscent of Chile at an earlier stage, with Peru in 2008 having a similar profile to Chile around 1980 (total tonnages are also very similar, with Chile's DMC in 1980 at 17.4 tonnes per capita). As for Chile, the changes in material shares are largely an indication of the extent to which Peru is increasingly functioning as an extractive hinterland for other industrialized economies.

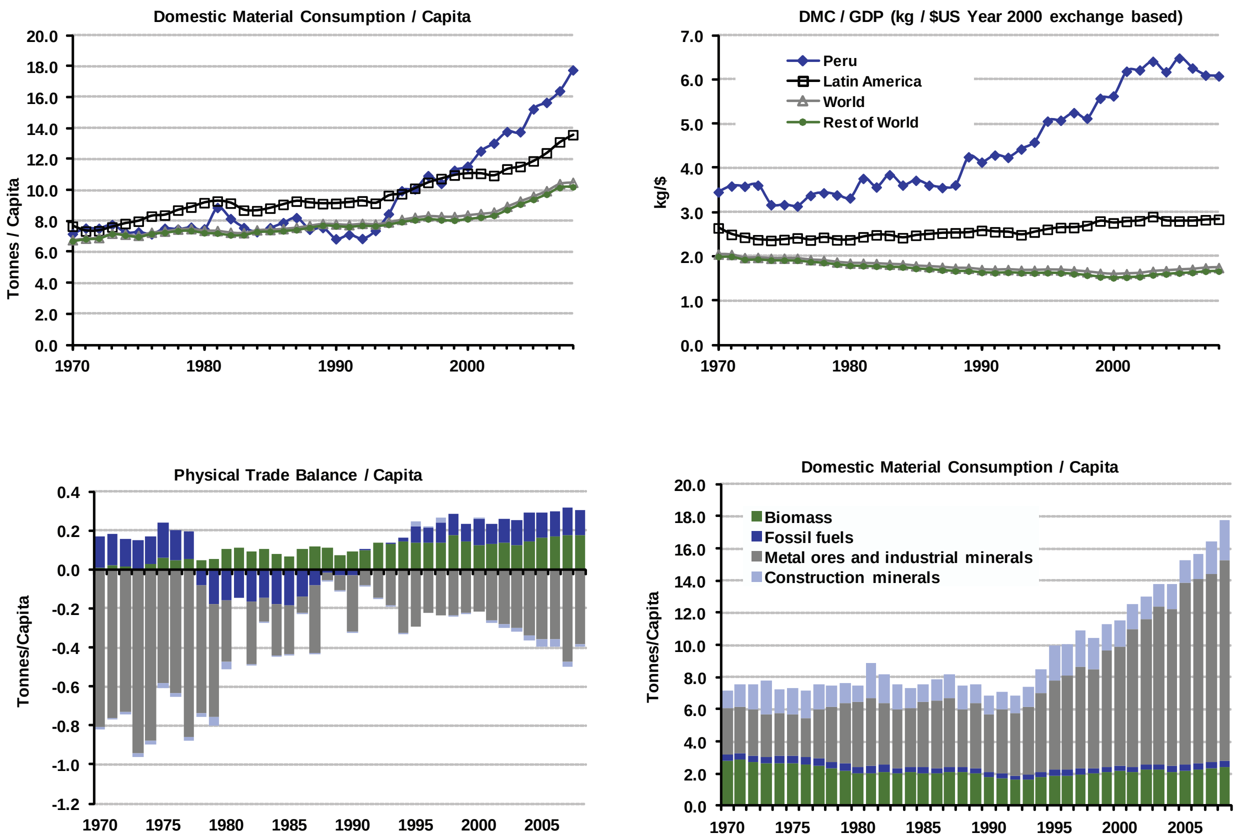

Figure 17 Summary panel of material flows and materials intensity for Peru

Net exports were dominated by metal ores. The ratio of metal exports to DMC is very low, due to the dominance of non-ferrous ores and their high concentration in trade. From being a net exporter of fossil fuels through the 1980s, Peru became increasingly reliant on imports again from the early 1990s. Detailed data shows that these imports are largely petroleum, which constitute around one third of Peru's DMC of petroleum. DMC of biomass per capita decreased between 1970 and the early 1990s, coinciding with Peru increasing net imports per capita in this category.

Peru's MI, at 3.5 kg per $US in 1970, was 31% higher than the regional average. It increased rapidly so that by 2008 it was 6.1 kg per $US, factors of 2.1 and 3.5 times the regional and world averages respectively. Rapid increases in MI closely coincide with rapid expansion in metal ores DMC, as expected as those ores are highly concentrated prior to trade.

5.10 Bolivarian Republic of Venezuela

Venezuela's DMC per capita of 7.9 tonnes in 1970 was slightly above the regional average. It grew very slowly over subsequent decades, to 8.9 tonnes per capita by 2008, although it peaked earlier at just below 10 tonnes per capita around 1980. Relative shares of DMC for the four major material categories stayed quite stable over the study period, with the exception of metal ores, which almost quadrupled from 2.8% to 10.4%. Biomass decreased from 33% to 28%, but construction materials also decreased from 39% to 37%, while fossil fuels began and ended the period at just below 25%. This relatively steady state, especially in biomass share, suggests that the transition away from an agrarian society was already complete in 1970, or at least had progressed as far as it would in Venezuela's particular circumstances, i.e. as an economy largely underpinned by exports of petroleum.

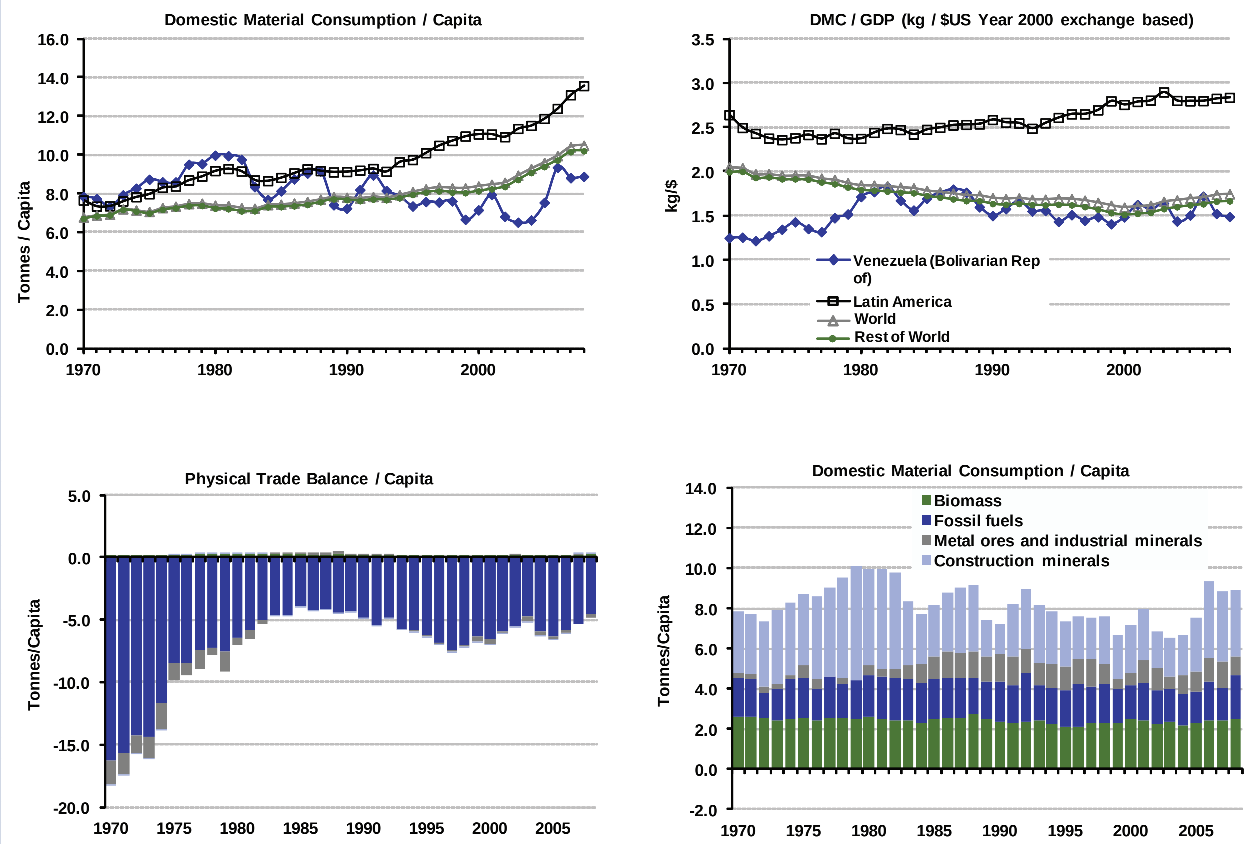

Figure 18 Summary panel of material flows and materials intensity for Venezuela

The graphic of the PTB shows near total dominance of fossil fuels in Venezuela's net exports, and these are overwhelmingly of petroleum. The rapid decline in fossil fuel exports from the 1970s to the 1980s may be more a result of political and market events over this time (e.g. oil embargoes, evolution of OPEC cartel and official production quotas from the early 1980s) rather than resource depletion, which appears important in other focus countries.

Venezuela's MI, at 1.25 kg per $US in 1970, was best of all focus countries, less than 48% of the regional average and 63% of the world average. It had increased to 1.5 kg per $US by 2008, but remained the best of all focus countries, and well below the world average.

6 Drivers of material use patterns and material efficiency

The level of resource use in a region is driven by a number of factors. To better understand how resource use has developed to the present, and what trajectory it might take into the future, it can be helpful to identify and analyse key drivers independently. One widely used analytical framework to achieve this is the IPAT equation ($I = P \times A \times T$). This equation in its original form proposed by (Ehrlich and Holdren 1971) conceptualizes total impacts on the environment (I) as the product of population (P), multiplied by the level of affluence of that population (A), multiplied by a technological coefficient (T).

I might be defined as an emission of interest, such as CO_2, or an extractive pressure on the environment, such as DMC. A is often taken to be GDP/capita, and then T could be defined as the intensity of I per unit GDP generated. Here, I = DMC, A = GDP/capita, and T[4] = DMC/GDP (which is the same as materials intensity, MI).

Using this framework in its original form, determining the effect on I of changing an individual driver in isolation is straightforward. A 10% increase in P will, all other things being equal, lead to a 10% increase in I. The situation becomes less clear where two or more of the drivers vary simultaneously, due to the multiplicative nature of the equation. A quick inspection of the percentage changes in drivers (DP, ∆A, and DT) in Table 5 shows that the change in impact (∆I) cannot be calculated by adding these changes. More importantly, it is difficult to allocate proportional responsibility for ∆I to the different drivers using IPAT in this form, and have the components add up to 100%.

One solution to this allocation problem is via a transformation of the IPAT factors to logarithmic form, giving an additive form of the IPAT equation, which is amenable to allocating percentage contributions to the different drivers, which will add up to 100%.[5] The results of applying this technique are shown in the last three columns of Tables 6 to 10.

4 The use of the term T in the original IPAT formulation is perhaps unfortunate, as people often equate an increase in 'small t' technology with an improvement in efficiency. In the IPAT context, T stands for a 'technological coefficient', which is then typically defined as whatever the environmental impact of interest is, divided by GDP. T can thus increase or decrease according to such things as changes in exchange rates, even if the underlying technologies used remain identical. This point is important. As we are interested in DMC, then T here is simply DMC / GDP, which is equivalent to MI. As a reminder, we do not use the word 'technology' interchangeably with T to remind the reader of this highly specific and perhaps counterintuitive definition.

5 Details on the formulation of the log transformation of IPAT and a discussion of some limitations of the technique can be found in Herendeen (1998). The values for Venezuela in Table 5 provide an illustration of one shortcoming. In cases where there have been changes in drivers, of opposite signs, which result in a small net change in I, we end up with very large percentage changes of opposing signs (which still add to 100%) to explain the small ∆I. In such cases, the raw percentage changes in P, A, and T provides a much clearer representation of the dynamics over the period.

Table 6 shows changes over the full study period. All focus countries posted strong population growth over the period, as did the region as a whole. There was a similar but generally weaker pattern for the level of affluence, although one focus country, Venezuela, actually posted a small decline in affluence. This is broadly similar to the world pattern overall, except that for Latin America population growth is a stronger driver of the environmental impact under consideration than affluence, whereas for the world overall they were roughly equal. At the individual country level, in only three countries (Brazil, Chile, and Colombia) was affluence equally or greater in importance than population growth. This strong linkage of an environmental impact to growth in population and wealth parallels Finding 10 in the report on resource efficiency in Latin America (UNEP 2011a), which highlights a linkage between GDP and population growth on the one hand, and energy related emissions on the other.

							Share contribution using log transforms		
	ΔI%	ΔI (tonnes)	$\Delta I_c/\Delta I$ [6]	ΔP	ΔA	ΔT	P	A	T
Brazil	375%	2,322,493,359	1.00	100%	124%	6%	44%	52%	4%
Mexico	235%	798,070,654	1.00	110%	84%	-14%	62%	51%	-12%
Chile	668%	929,996,109	1.00	76%	182%	55%	28%	51%	22%
Argentina	91%	291,743,029	1.00	66%	49%	-23%	79%	62%	-41%
Peru	441%	416,987,575	1.00	119%	41%	76%	46%	20%	33%
Colombia	183%	205,165,984	1.00	111%	111%	-36%	72%	72%	-44%
Venezuela	195%	164,127,317	1.00	161%	-5%	19%	88%	-5%	16%
Ecuador	332%	100,508,568	1.00	126%	88%	2%	56%	43%	1%
Guatemala	371%	73,906,163	1.00	152%	51%	23%	60%	27%	13%
Bolivia	333%	64,789,225	1.00	130%	26%	49%	57%	16%	27%
Latin America	258%	5,528,890,032	1.08	102%	78%	7%	52%	43%	5%
World	184%	45,336,125,279	0.99	82%	82%	-15%	58%	58%	-15%

Table 6 Major drivers of the change in domestic material consumption for the 10 largest consumer nations in Latin America over the period 1970 to 2008

With regard to T, seven of the ten focus countries showed T acting to increase I. This is significant in that, while a regional increase in MI may occur even where most countries are successfully decreasing their individual MI (see discussion around Figure 7 above), this is clearly not what is happening in Latin America. It implies that one of the initial requirements for decreasing I while simultaneously raising or even maintaining material living standards has not generally been taken in the most important countries in the region. Those countries with relatively large non-ferrous mining sectors perform worst on T.

6 Each of the values I, P, A, and T in the tables are determined independently. I for a region will include all DMC data available for each year / country data point in that region, however A and T will only include data for each year / country data point where both GDP and population, or DMC and GDP, are simultaneously available. This means that while I = PAT will hold strictly for individual countries, it will often not hold for multiple country regions, as regional values for I, P, A, and T can all come from slightly different subsets of country / year data points. The Ic/I column here shows the ratio between the change in Ic (DMC) which would be calculated from P, A, and T, and that which has been directly compiled from base data. The extent to which this ratio differs from 1 indicates how strong this effect is for the period.

	ΔI%	ΔI (tonnes)	$\Delta I_c/\Delta I$	ΔP	ΔA	ΔT	Share contribution using log transforms P	A	T
Brazil	86%	531,478,299	1.00	27%	78%	-17%	38%	93%	-31%
Mexico	69%	233,950,889	1.00	34%	43%	-12%	55%	69%	-24%
Chile	40%	55,311,029	1.00	17%	14%	5%	46%	38%	15%
Argentina	16%	50,067,791	1.00	17%	14%	-13%	110%	88%	-99%
Peru	37%	35,008,868	1.00	31%	9%	-4%	87%	26%	-13%
Colombia	50%	55,937,541	1.00	26%	36%	-12%	57%	75%	-32%
Venezuela	79%	66,362,841	1.00	41%	-7%	37%	59%	-13%	54%
Ecuador	80%	24,163,677	1.00	33%	48%	-9%	49%	66%	-15%
Guatemala	67%	13,307,541	1.00	29%	34%	-4%	50%	57%	-7%
Bolivia	51%	10,000,311	1.00	27%	15%	3%	58%	34%	8%
Latin America	52%	1,117,432,693	1.03	27%	37%	-10%	53%	71%	-24%
World	32%	7,919,652,804	0.99	21%	21%	-10%	68%	70%	-38%

Table 7 Major drivers of the change in domestic material consumption for the 10 largest consumer nations in Latin America over the period 1970 to 1980

Tables 7 through 10 show the IPAT analyses performed for decadal time slices. In Table 7, which covers 1970 to 1980, seven out of the ten focus countries show a decrease in T, and that the region as a whole also showed a reasonably strong decrease of –10%, in line with the world average for the period, and the only decade where the region posted an improvement in MI. The decrease in T was far outweighed by increases in population and its affluence levels, so that I increased by 52% over the period, considerably higher than the 32% global figure. Affluence, which increased at nearly twice the global average rate, accounted for the largest portion of the increase in I for Latin America over this period.

	ΔI%	ΔI (tonnes)	$\Delta I_c/\Delta I$	ΔP	ΔA	ΔT	Share contribution using log transforms P	A	T
Brazil	26%	295,525,716	1.00	23%	-5%	8%	90%	-23%	32%
Mexico	30%	173,475,505	1.00	23%	-3%	9%	79%	-12%	33%
Chile	63%	122,427,256	1.00	18%	23%	13%	34%	42%	24%
Argentina	-10%	-36,738,260	1.00	15%	-26%	5%	-138%	284%	-46%
Peru	15%	19,427,508	1.00	26%	-27%	25%	164%	-221%	157%
Colombia	30%	49,730,271	1.00	23%	15%	-9%	81%	55%	-36%
Venezuela	-5%	-7,844,720	1.00	31%	-17%	-13%	-503%	349%	253%
Ecuador	27%	14,674,714	1.00	29%	-5%	4%	107%	-23%	17%
Guatemala	64%	21,232,963	1.00	27%	-14%	50%	48%	-30%	82%
Bolivia	35%	10,346,860	1.00	25%	-19%	34%	73%	-69%	96%
Latin America	22%	713,679,100	1.00	23%	-8%	9%	101%	-44%	43%
World	26%	8,544,041,368	0.99	19%	14%	-8%	76%	60%	-36%

Table 8 Major drivers of the change in domestic material consumption for the ten largest consumer nations in Latin America over the period 1980 to 1990

In Table 8 we see that, contrary to the world trend for this period, affluence in Latin America decreased quite strongly, by –8 % regionally, with eight of the ten focus countries suffering decreasing affluence. It is also over this period that T accounts for its largest share of the increase in MI for any period, increasing in eight of the ten countries analysed, and growing by 9% regionally, more than offsetting the contribution that declining affluence made to limiting growth in I. This is contrary to the ongoing global improvement in T, where MI decreased by –8%. Population growth was less than in the preceding period, but still well above world average, and contributed by far the most to increasing I for this period. The increase in I for the full Latin America region was below the world average for this decade.

							Share contribution using log transforms		
	ΔI%	ΔI (tonnes)	$\Delta I_c/\Delta I$	ΔP	ΔA	ΔT	P	A	T
Brazil	36%	520,413,836	1.00	16%	10%	6%	50%	32%	18%
Mexico	24%	181,072,464	1.00	18%	20%	-12%	75%	82%	-57%
Chile	179%	567,929,134	1.00	17%	59%	50%	15%	45%	40%
Argentina	42%	140,810,345	1.00	14%	37%	-9%	36%	90%	-27%
Peru	101%	150,766,598	1.00	19%	24%	36%	25%	30%	44%
Colombia	26%	56,974,184	1.00	20%	7%	-2%	78%	29%	-7%
Venezuela	22%	30,761,864	1.00	23%	0%	-1%	106%	-1%	-5%
Ecuador	16%	11,181,102	1.00	20%	0%	-3%	120%	-1%	-19%
Guatemala	42%	22,791,250	1.00	26%	19%	-5%	66%	49%	-15%
Bolivia	35%	13,973,369	1.00	25%	16%	-7%	73%	50%	-23%
Latin America	43%	1,691,615,360	1.04	18%	18%	7%	42%	42%	16%
World	24%	9,797,934,834	1.00	15%	15%	-6%	66%	64%	-31%

Table 9 Major drivers of the change in domestic material consumption for the 10 largest consumer nations in Latin America over the period 1990 to 2000

Table 9, for the period 1990 to 2000, shows population growth easing further in the region, while affluence returns to relatively strong growth with only two individual countries suffering a further decline in affluence. As a result, growth in population and affluence make a roughly equal contribution to the increase in I; this is the case for the world generally, although global rates of growth in population and affluence are both lower. T again runs contrary to the world trend towards decreasing MI, and so acts to increase growth in I regionally, rather than moderating it. There are some very large increases in individual T values for Chile and Peru, as non-ferrous mining activity increased strongly there. Overall, Latin America through this period experienced growth in population, affluence and T moderately higher than world averages. The three factors combined to drive the regional increase in I at a rate 80% faster than the world average.

	ΔI%	ΔI (tonnes)	$\Delta I_c/\Delta I$	ΔP	ΔA	ΔT	Share contribution using log transforms P	A	T
Brazil	50%	975,075,507	1.00	10%	20%	13%	24%	45%	30%
Mexico	23%	209,571,796	1.00	9%	11%	2%	40%	52%	8%
Chile	21%	184,328,689	1.00	9%	27%	-13%	45%	128%	-73%
Argentina	29%	137,603,153	1.00	8%	29%	-7%	30%	99%	-29%
Peru	71%	211,784,601	1.00	11%	43%	8%	19%	66%	14%
Colombia	15%	42,523,988	1.00	13%	26%	-19%	86%	162%	-148%
Venezuela	43%	74,847,332	1.00	15%	24%	1%	39%	60%	1%
Ecuador	63%	50,489,075	1.00	10%	35%	10%	19%	62%	20%
Guatemala	21%	16,574,409	1.00	22%	11%	-10%	102%	53%	-55%
Bolivia	57%	30,468,685	1.00	17%	16%	16%	34%	33%	33%
Latin America	35%	2,006,162,879	1.01	10%	20%	3%	32%	59%	9%
World	37%	19,074,496,272	1.00	10%	14%	10%	30%	42%	28%

Table 10 Major drivers of the change in domestic material consumption for the 10 largest consumer nations in Latin America over the period 2000 to 2008

Results for the period from 2000 to 2008 are shown in Table 10. Population growth rates in Latin America slow markedly over this period, with four of the focus countries below the world average, although Guatemala's population continued to grow at more than twice the world rate. Regional affluence grows strongly, at 20%, well in excess of the world average, and accounts for 59% of the regional increase in I. T grew by 3%, and so accounted for a relatively modest 9% of regional increase in I over the period, while at the individual country level, six of the focus countries showed increases in T, although at relatively low rates compared to those seen in the preceding two periods. While T continued to grow regionally, for the first time regional performance on this measure was better than the world average, where MI grew by 10%. It is likely that the increase in commodity prices over this period was an important factor in this result. Considering the scale of commodity price increases over the period, it is perhaps surprising that T did not decrease much more for a country like Chile, and continued to increase for Peru, both of which have large exports of non-ferrous metals. This will certainly have been driven to some extent by decreasing average ore grades, with the attendant requirement to extract more ore per unit of commodity exported. The regional increase in I was lower than the world average. While this was the case for one previous decade (from 1980 to 1990), on that occasion it was driven by a major decrease in affluence in the region.

7 Final Remarks

In observing how the relative importance of population, affluence, and T changes over the different periods outlined in section 6, several key points emerge. Firstly, T has not served to restrain growth in materials consumption in the region for almost three decades, from 1980 to 2008, and so a minimum condition for even weak decoupling of materials from economic growth has not been achieved since the initial decade (1970 – 1980). This fact is of direct relevance to Finding 3 of the report on resource efficiency for Latin America (UNEP 2011a), concerning the need for tremendous improvements in resource efficiency to achieve sustainability. Only in Colombia did T act as a restraint on growth in I for each period analysed, and even so that country still had DMC grow by over 180% over the full period. Argentina achieved the lowest growth in I of all focus countries, at 91%. Looking at the individual decades, it can be seen that this was achieved via a combination of consistently low population growth rates, reasonably consistent decreases in T, and very moderate growth in affluence. In no case does any country post a decline in I over a decade which could be attributed to T, indicating that there is no sign as yet of an Environmental Kuznets Curve operating for any of the focus countries in relation to DMC. It is also apparent that those countries which increase their function as extractive hinterlands for other industrialized countries will have a strong tendency towards increasing T over the longer term, especially where they specialize in extraction of non-ferrous metals. This lends further weight to the idea that the tendency to primarization noted in UNEP (2011a) makes achieving higher resource efficiency, at least as measured by MI, more difficult.

There were only two occasions where declines in total DMC took place i.e. for Venezuela and Argentina from 1980 to 1990, and in both cases the main driver was strong decreases in affluence (although T did make a sizeable contribution in Venezuela's case). This point is important, in that in a region composed mainly of developing countries, reducing environmental impacts by reducing affluence would definitely be seen as policy failure, undercutting the political imperative of raising material living standards.

More encouraging is the fact that at least the rate at which materials efficiency has been deteriorating slowed considerably in the latest period, with MI increasing only 3% regionally. Also, the relatively rapid growth in population which was been the main driver of growing DMC in the region showed a strong and steady trend towards decline in each period, making the task of just maintaining material living standards for all proportionally easier to achieve.

8 Epilogue: a note on the scope of this report

The objectives of this this report are to establish empirical evidence of material flows and resource productivity for as many countries in the Latin America region as possible, and to provide technical background to accompany the database, also covering some Caribbean countries, available at www.csiro.au/LatinAmericaCaribbeanResourceFlows.

The authors are aware that this report does not cover the socio-economic aspects of uneven development related to extractive industries dominating national economies in many countries in Latin America. This was not part of the project and hence is not within the scope of the report. This is, however, a highly sensitive issue in the region and deserves acknowledgement. This section lists some of the other concerns currently in play in Latin America, and provides extra references for those readers who would like more context around the material flows presented here.

- For research comparing material consumption against the economic development of countries and regions in Latin America, please see CEPAL (2007).
- For analysis of how Uruguay responded to the 2002 financial crisis, please see World Bank and Ministerio de Economía y Finanzas (2007). For a discussion of economic growth patterns and income inequality in Chile, please see Infante and Sunkel (2009).
- For discussions on the environmental implications of development activities in Latin America, please see Ramos (2010), Schatan (1998), Prebisch (1983) and Dittrich et al. (2012); and for more information on the environmental implications of development activities in Chile, please see Quiroga (1995).
- For material flows studies relating to individual countries or small groups of countries, please see Giljum (2004 – for Chile), González-Martínez and Schandl (2008 – for Mexico), Vallejo, Pérez-Rincón and Martínez-Alier (2011 – for Colombia), Russi et al. (2008 – for Chile, Ecuador, Mexico and Peru), Pérez-Rincón (2006 – for Colombia), Vallejo (2010 – for Ecuador), Eisenmenger et al. (2007 – for Brazil, Chile and Venezuela), and Perez Manrique et al. (2012 – for Argentina). For more general information on accounting for material flows, see Krausmann et al. (2008), Matthews et al. (2000) and Eurostat (2011).
- For historical background on economic development and structural reform in Latin America, please see Prebisch (1950), Furtado et al. (1984), Griffith-Jones and Sunkel (1986), Schaffner (1994), Hounie et al. (1999), Pengue (2005), Pérez-Rincón (2006) and United Nations (2011).
- For discussions of unequal exchange and inequalities in distribution, please see Hornborg (1998) and Martínez-Alier (2002). For recent discussions on environmental conflicts related to extractive industries, please see Gudynas (2012), Gudynas and Acosta (2011) and Acosta (2009).

References

Acosta, A. (2009). *La maldición de la abundancia.* Quito, Ecuador: Ediciones Abya-Yala.

CEPAL (2007). Progreso técnico y cambio estructural en América Latina. Comisión Económica para América Latina y el Caribe, Santiago, Chile: UN.

Dittrich, M., S. Giljum, S. Lutter & C. Polzin (2012). Green economies around the world? Implications of resource use for development and the environment. Vienna: SERI.

Ehrlich, P. R. & J. P. Holdren (1971). Impact of Population Growth. *Science*, 171, 1212-1217.

EIA (2011). International Energy Statistics. U.S. Energy Information Administration.

Eisenmenger, N., J. Ramos Martin & H. Schandl (2007). Análisis del metabolismo energético y de materiales de Brasil, Chile y Venezuela. *Revista Iberoamericana de Economía Ecológica*, 6, 17–39.

Eurostat (2011). Economy Wide Material Flow Accounts (EW-MFA): Compilation Guidelines for Eurostat's 2011 EW-MFA questionnaire.

FAO (2011a). Subscribers section – Bulk downloads – Food balance sheets. Food and Agriculture Organization of the United Nations.

FAO (2011b). Subscribers section – Bulk downloads – Forestry. Food and Agriculture Organization of the United Nations.

FAO (2011c). Subscribers section – Bulk downloads – Production. Food and Agriculture Organization of the United Nations.

FAO (2011d). Subscribers section – Bulk downloads – Trade. Food and Agriculture Organization of the United Nations.

Furtado, C., A. Ferrer & R. Prebisch. 1984. *Para construir la democracia*. Buenos Aires, Argentina: El Cid Editor.

Giljum, S. (2004). Trade, material flows and economic development in the South: The example of Chile. *Journal of Industrial Ecology*, 8, 241–261.

González-Martínez, A. C. & H. Schandl (2008). The biophysical perspective of a middle income economy: Material flows in Mexico. *Ecological Economics*, 68, 317–327.

Griffith-Jones, S. & O. Sunkel (1986). *Debt and Development Crises in Latin America: The End of an Illusion.* Oxford: Oxford University Press.

Gudynas, E. (2012). Estado compensador y nuevos extractivismos: Las ambivalencias del progresismo sudamericano. *Nueva Sociedad*, 237, 128–146.

Gudynas, E. & A. Acosta (2011). La renovación de la crítica al desarrollo y el buen vivir como alternativa. *Utopía y Praxis Latinoamericana,* 16, 71–83.

Hornborg, A. (1998). Towards an ecological theory of unequal exchange: articulating world system theory and ecological economics. *Ecological Economics,* 25, 127–136.

Hounie, A., L. Pittaluga, G. Porcile & F. Scatolin (1999). ECLAC and the new growth theories. *CEPAL Review,* 68, 7–34.

IEA (2011a). Energy balances of non-OECD countries. Paris: International Energy Agency.

IEA (2011b). Energy balances of OECD countries. Paris: International Energy Agency.

IEA (2011c). Energy statistics of non-OECD countries. Paris: International Energy Agency.

IEA (2011d). Energy statistics of OECD countries. Paris: International Energy Agency.

Infante, R. B. & O. Sunkel (2009). Chile: towards inclusive development. *CEPAL Review*, 97, 133–152.

Krausmann, F., M. Fischer-Kowalski, H. Schandl & N. Eisenmenger (2008). The Global socio-metabolic transition: past and present metabolic profiles and their future trajectories. *Journal of Industrial Ecology*, 12, 637–656.

Martínez-Alier, J. (2002). *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*. Cheltenham: Edward Elgar.

Matthews, E., C. Amann, S. Bringezu, M. Fischer-Kowalski, W. Hüttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schütz, E. Van der Voet & H. Weisz (2000). *The Weight of Nations. Material Outflows from Industrial Economies*. Washington, DC: World Resources Institute.

Pengue, W. A. (2005). Agricultura industrial y transnacionalizacion en America Latina: ¿La transgénesis de un continente? In *Serie Textos Básicos para la Formación Ambiental*. México D.F., México: PNUMA.
Pérez-Rincón, M. A. (2006). Colombian international trade from a physical perspective: Towards an ecological 'Prebisch thesis'. *Ecological Economics*, 59, 519–529.
Perez Manrique, P., J. Brun, A. C. Gonzalez-Martinez, M. Walter & J. Martinez-Alier (2012). The Biophysical Performance of Argentina (1970–2009). *Journal of Industrial Ecology*, In press.
Prebisch, R. (1950). The Economic Development of Latin America and Its Principal Problems. Lake Success, NY: United Nations.
Prebisch (1983). Biósfera y desarrollo. In *Ecodesarrollo, el pensamiento del decenio*, eds. M. Marino de Botero & J. G. Tokatlián, 261–287. Caracas.
Quiroga, R. (1995). El Tigre sin Selva: consequencias ambientales de la transformación economica de Chile. Santiago: Instituto de Ecologia Politica, IEP.
Ramos, G. C. D. (2010). Ecología Política de la Minería en América Latina: Aspectos Socioeconómicos legales y ambientales de la mega minería. Coyoacán, México: Universidad Nacional Autónoma de México.
Russi, D., A. C. Gonzalez-Martinez, J. C. Silva-Macher, S. Giljum, J. Martínez-Alier & M. C. Vallejo (2008). Material Flows In Latin America: A Comparative Analysis of Chile, Ecuador, Mexico and Peru, 1980-2000. *Journal of Industrial Ecology*, 12, 704–720.
Schaffner, J. A. (1994). On Osvaldo Sunkel´s (ed.) Development from Within: Toward a Neostructuralist Approach for Latin America. *Journal of Economic Literature*, 32, 54–55.
Schatan, J. (1998). *El Saqueo de América Latina: Deuda Externa, Neoliberalismo, Globalización.* Santiago: LOM Ediciones/Universidad Arcis.
UN Statistics Division (2006). Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings. New York: UNSD.
UN Statistics Division (2011a). Commodity Trade Statistics Database, United Nations.
UN Statistics Division (2011b). Industrial Commodity Production Statistics Database 1950–2008. New York.
UNEP (2011a). Resource Efficiency: Economics and Outlook for Latin America. Panama City: United Nations Environment Programme.
UNEP (2011b). Resource Efficiency: Economics and Outlook for Asia and the Pacific. Bangkok: United Nations Environment Programme.
UNEP (2013). Recent trends in material flows and resource productivity in Asia and the Pacific. CSIRO and UNEP.
United Nations (2011). Información histórica – Evolución de las ideas de la CEPAL. United Nations.
USGS (2011). Commodity Statistics and Information. United States Geological Survey.
Vallejo, M. C. (2010). Biophysical structure of the Ecuadorian economy, foreign trade, and policy implications. *Ecological Economics*, 70, 159-169.
Vallejo, M. C., M. Pérez-Rincón & J. Martínez-Alier (2011). Metabolic profile of the Colombian Economy from 1970 to 2007. *Journal of Industrial Ecology*, 15, 245–267.
West, J. (2012). Material flows database for Latin America and the Caribbean. Canberra: CSIRO.
World Bank and Ministerio de Economía y Finanzas (2007). Uruguay: ¿qué aprendimos de la crisis financiera de 2002? Montevideo, Uruguay.

United Nations Environment Programme (UNEP)
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
Email: uneppub@unep.org
http://www.unep.org

Programa de las Naciones Unidas para el Medio Ambiente (PNUMA)
Oficina Regional para América Latina y el Caribe,
Avenida Morse, Edificio 103. Clayton,
Ciudad del Saber, corregimiento de Ancón,
Panama city, Panama / P.O. Box 03590
Tel.: (+507)305-3100 / Fax: (+507)305-3105
Email: enlace@pnuma.org / **http:/www.pnuma.org**

UNEP

This report is intended to supplement the original 'Resource Efficiency in Latin America: Economics and Outlook' (UNEP 2011) report. The content herein is based on a new material flows database established for the Latin America and Caribbean region, which was created subsequent to the earlier report. The scope of this report is considerably narrower than the original report, focussing on deepening quantitative analyses specifically relating to primary material flows, and the trajectories of related resource efficiency indicators.

DEW/1578/PA