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Material Flow Analysis of Argentina (1970- 2009)[1]

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Material Flow Analysis of Argentina (1970- 2009)

Julien Brun, Pedro Luis Perez Manrique, Ana Citlalic González-Martínez, Mariana Walter and Joan Martínez-Alier

Abstract

This paper studies the biophysical features of the Argentinean economy using the approach of social metabolism. A Material Flow Analysis (MFA) of this economy was conducted for the period 1970-2009.

Keywords

Material flow accounting, extractive economies, societal metabolism, ecologically unequal exchange, Argentina.

Contents

1. Introduction

World economic growth and trade liberalization in Latin American have generated a surge of commodity flows from this region to the rest of the world in the last thirty years. Argentina is one of the major South American economies. The country has increased its international trade based on a strong agricultural sector and a growing mining industry. In 2008, it was the 4th gold and 5th copper producer in Latin America in terms of mass output (USBM 2011), 3rd producer of soybeans and 5th producer of maize of the world (FAOSTAT 2010). Such economic performance has direct impacts on the environment. An increasing number of resource extraction conflicts are reported (Svampa and Antonelli 2009, Binimelis et al 2009).

By using the approach of social metabolism (Ayres and Simonis 1994; Fischer-Kowalski 1998), the biophysical pattern of economies can be quantified. This paper presents the metabolic profile of the Argentinean economy between 1970 and 2009 by means of an economy-wide material flow analysis (EW-MFA). A similar study, based on international data sources, was carried out by the Sustainable Europe Research Institute for the period 1980-2008 (SERI 2012). Both studies are consistent, with a small average difference per year of 13% in total Domestic Extraction. The novelty of our research lies in the length of the period of study, 40 years, and the use of national data sources.

The EW-MFA has been widely applied to OECD countries. Recent studies have also been conducted for Chile, Peru, Mexico, Ecuador, Colombia and Brazil (Giljum 2004; Russi et al. 2008; Gonzalez-Martinez and Schandl 2008; Vallejo, 2010; Vallejo et al. 2011; Eisenmenger et al. 2007). These analyses describe the metabolic profile of peripheral economies over long periods and help to understand the socio-ecological implications of their trade patterns.

Argentina is the third largest Latin American economy (after Brazil and Mexico), having a long history of exploitation of natural resources. In addition, this country experienced several crises and structural changes during the past forty years with effects on the biophysical structure of its economy. In the current international economic turmoil, it is one of the countries having economic growth.

This paper is structured in five sections. **Section 1** is the current introduction. **Section 2** presents the MFA methodology. **Section 3** summarizes the economic history of Argentina of the past four decades. **Sections 4** analyses the main material flow indicators such as Domestic Extraction (DE), Physical Imports (M) and Exports (X) and derived indicators. Results are compared and discussed with similar studies carried out for Spain and other Latin American countries. **Section 5** addresses the question of the terms of trade in the integration of Latin American countries in the global economy.

The comparison with Spain is motivated by two reasons. Firstly, in the past these two countries shared the same level of wealth. For instance, in 1970, GDP per capita (US$ constant, base 2000) in Argentina was 11.7% higher than in Spain. In 2009, GDP per capita of Spain was three times higher than GDP per capita in Argentina, although at present Argentina GDP is growing fast while Spain stagnates (after the end of the building boom). Secondly, their strategies of integration into the world economy have diverged. Spain is a typical European net importer of natural resources in physical terms whereas Argentina is a large net exporter. Besides, their population is similar. The population of Spain was 33.8 million inhabitants in 1970 and 46 million in 2009, while Argentina

increased from 24.0 million to 40.1 million (INDEC 2011; INE 2011). However the population density is five times larger than that of Spain. In conclusion, Spain was quite similar to Argentina in some respects in 1970, but their development has diverged since then. It is therefore interesting to compare if the metabolic profiles of these two countries have diverged as well, and in which respects they have differed.

2. Methods and sources

This biophysical analysis of Argentina's economy rests on the approach of Social Metabolism, used to analyze the physical base of socioeconomic systems in the fields of Ecological Economics and Industrial Ecology (Schandl and Schulz 2000). *Social Metabolism* refers to the overall material and energy exchanges between a society and its environment in order to sustain itself or to grow (Fischer-Kowalski 1998). Based on the material balance principle, all materials that enter into the economic system must be equal to material outputs plus the material accumulation into the system. The flow of materials into the system allows to construct and maintain "the system's material compartments" (stocks). In this sense, all the materials required to maintain these *material compartments,* are considered essential for the system performance (Fischer-Kowalski et al. 2011).

The *economy-wide material flow analysis,* defined as "a consistent compilation of the overall material inputs into national economies, the material accumulation within the economic system and the material outputs to other economies or to the environment" (EUROSTAT 2001 p.17), provides a physical description of an economic system. This methodology allows to account for input flows (biomass, fossil fuels, construction minerals, etc.) and output flows (exports, waste, pollutant emissions).

This article focuses on the input side by taking into account all the materials that enter into the national economy —except for water and air. Only direct flows were considered (Fischer-Kowalski et al. 2011). We also give information about the physical dimension of foreign trade. We define terms of trade (TOT) as the average weight of imports that can be purchased through the sale of one tonne of exports.

Three basic flows are measured: Domestic extraction (DE), which is the weight of harvested or extracted materials in the national territory entering the production process, and the physical imports (M) and exports (X).

These three basic flows are used to construct three main macro indicators, defined in EUROSTAT (2001):

- Direct material input (DMI = DE + M) accounts for the total input flowing into the national economy.
- Domestic material consumption (DMC = DMI -X) sums all materials used domestically (EUROSTAT, 2001, p.38).
- Physical trade balance (PTB = M - X) represents the net physical flow through the national borders. It is the physical equivalent to the Monetary Trade Balance (MTB = Export value – Import value). Nevertheless, money and mass goods move in opposite directions in economies, which is the reason for inverse order of imports and exports in the above equations.

Table 1 presents the main material groups analyzed (i.e. Biomass, Minerals and Fossil Fuels) and the sources of data used for the analysis of the Domestic Extraction. For each flow we calculated the annual amount in tonnes of raw materials extracted from the national territory in order to be used as material factors in the economic system. National official statistics were preferably used, if not, international sources were brought in.

Table 1: Domestic extraction categories and sources

Categories	sub-category	Description	Data sources
Biomass *Biological material used by humans and livestock.*	Primary Crops	Cereals, roots and tubers, pulses, oil crops, vegetables, fruits, tree nuts and other crops (stimulants, sugar cane, spices, and flowers).	FAO (2010), MAGyP (2011)
	Forage	Crops destined to produce forage and silage for livestock feeding	FAO (2010), MAGyP (2011)
	Grazed biomass	Demand for forage of livestock units	Annual livestock and permanent pasture data: FAO (2010) Permanent pasture or grasses productivity: FAO (2010) Organic matter demand estimation: Weisz et al. 2007
	By-products of harvest	Crop residues of sugar cane and cereals used as forage for livestock	FAO (2010), MAGyP (2011) Straw Coefficients: Wirsenius, 2000, p. 102
	Fishing	Captures of fish, crustaceans, mollusks, and aquatic invertebrates.	FAO (2010)
	Forestry	Wood harvested from forests, plantations, or agricultural lands: fuel wood, roundwood and wood roughly prepared.	FAO (2010)
Minerals	Metal Ores	Metal ores production measured as gross ore.	SMRA (1993, 2011), USBM (2011)
	Industrial Minerals	Minerals for industrial use	SMRA (1993, 2011)
	Construction Minerals	Sand and gravel used for concrete and other building materials.	SMRA (1993, 2011) Cement production statistics: USBM (2011)
Fossil fuels		Production of coal, oil, natural gas and others fossil fuels	SMRA (1993, 2011), SERA (2000, 2011) and IEA (2010a)

Source: adapted from Gonzalez-Martinez (2008)

Biomass

Fodder for livestock –which is a major flow in Argentina– is not fully accounted for in official statistics. This flow consists of three subcategories: forage, by-products and grazing. Forage is the primary crops used for feeding animals. By-products are the by-products of crop harvest used as fodder such as fodder beet leaves or sugar beet leaves. Grazing is the grass uptake from pastures. Forage data was taken from the FAO database (FAO 2010) and national sources (MAGyP 2011). By-products were calculated applying conversion factors developed for Latin America by Wirsenius (2000) to agricultural harvest taken over from FAO (2010) and national sources (MAGyP 2011).

To estimate grazing, we calculated the potential supply and potential demand of animal fodder from permanent pastures and the lower value was used as suggested by EUROSTAT (2002). This procedure avoids the over estimation of grazing. Potential supply was estimated by multiplying the areas of permanent pastures by the annual yield coefficients provided by the FAO (FAO 2010). Potential demand was calculated as the average feed demand (measured in mass unit) by type of livestock (Weisz et al. 2007), multiplied by the annual livestock (FAO 2010) and minus the previously estimated amounts of forage and by-products. Calculated demand was lower than estimated biomass supply from grazing land, hence, we calculated grazed biomass as the difference between calculated roughage demand and available feed from crop residues and forage.

Concerning animal domestic extraction, only biomass extraction from fishing was considered since data on hunting was not available. However, hunting is expected to be a relatively small fraction of the total biomass flow.

Minerals

Concerning metal ores, national statistics provide the most homogeneous data in terms of the mass of the metallic content (SMRA 1993 2011). However, the EW-MFA accounts for the mass of the extracted ores (or run-of-mine), hence we have estimated this figure by using the average metallic contents of the major local deposits based on the annual reports prepared by the main mining companies, the USBM annual commodity report and the USBM Mineral Commodity Profiles.

Regarding the extraction of construction materials, sand and gravel –which represent the main flow of this category- are not well reported in statistics (Bringezu and Schutz 2001; EUROSTAT 2002), requiring an indirect estimations. We applied a method that correlates the extraction of sand and gravel with the production of cement. According to Krausmann et al. (2009), 6.5 tons of sand, gravel and filling material are needed for 1 ton of cement domestically produced. Long term cement production figures were provided by the USBM mineral yearbook (USBM 2011). These estimates were completed with national extraction accounts of other construction minerals.

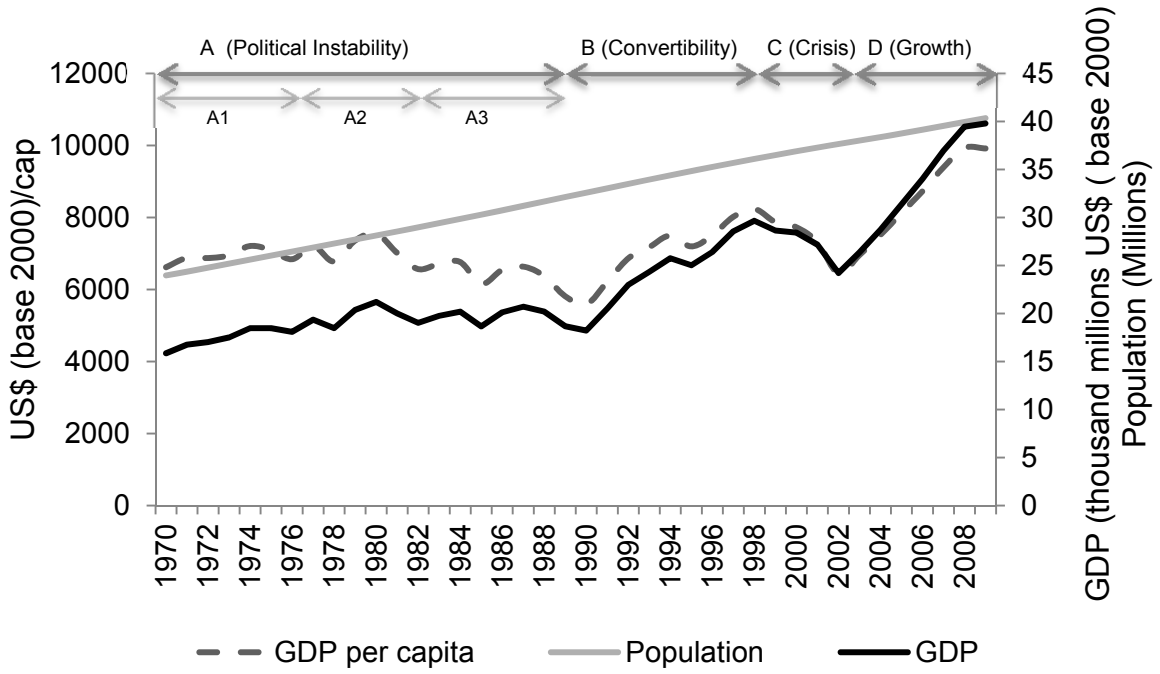
Foreign trade

For monetary and physical trade figures we used the commodity trade database (COMTRADE) of the United Nations Statistics Division, following the SITC revised 2 classification (UNSD, 2009a).

3. Argentina's economic overview

Changes in Argentina's GDP fall into four different stages during the period of study (Figure 1). (A) From 1970 to 1990 there was a turbulent period marked by political and economic instability with GDP and GDP per capita annual growth rates averages of 0.82% and -0.7%. (B) From 1991 to 1998 there was a period of GDP growth driven by liberalization policies. During these years the average GDP and GDP per capita growth rates were 6.3% and 5% respectively. (C) From 1998 to 2002, Argentina lived a social and economic crisis that led to the devaluation of the national currency. (D) Finally, from 2003 to 2009, a strong GDP growth phase was fostered by the expansion of commodity exports. During this period average annual growth of GDP and GDP per capita were 7.3% and 6.3% respectively.

Figure 1: Argentina population, GDP and GDP per capita (1970—2009).



Source: own elaboration based on WB (2011). *Note: GDP is in US$ constant, base 2000.*

A. 1970-1990. A period of political instability

A.1. 1970-1975."Import Substitution Industrialization" policies

Between 1930 and 1975, macro-economic policies were based on the development of Industries to substitute imports (ISI policies). Industry development focused on the domestic market and a strong protectionist scheme was adopted with high import restrictions and tariff levels. The government played a key role via subsidies, loans and service provision.

During the period 1970-1975, ISI policies fostered economic growth, however, the structural problem of the restriction to capital access persisted, resulting in a domestic industry based on the production

of low added-value products. Moreover, ISI measures fostered inflation and a negative monetary trade balance as the model initially required foreign capital and intermediate goods imports. Furthermore, the government discouraged the export sector by taxing agricultural exports widening the monetary trade imbalances which ultimately was solved through inflation. In 1972, the inflation rate was of 90% and in 1975 a new inflation crisis occurred with an annual inflation rate of 566% (Gorosito et al. 1998).

A.2. 1976-1983. Neoliberal policies

In March of 1976, armed forces took power. The dictatorship implemented neoliberal economic policies, as already in practice by force in Chile and Uruguay. The main economic measures implemented were the abolishment of ISI policies, the trade opening and the economic liberalization. Treber (1987) and Ramos (1986) underline that although neoliberal policies reduced inflation and boosted exports, they were unsuccessful regarding growth. As shown in Figure 1, the average GDP growth rate was 0.5 %.

A.3.1983-1990. The democratic transition

The military government collapsed in 1982 after losing the Malvinas War against the United Kingdom. In 1983, Raúl Alfonsín won free elections initiating the democratic transition. He promoted new import substitution measures as an alternative to the failed economic liberalization experience (ECLAC 1984). However, an economic crisis reappeared in 1989. Inflation reached its peak in July of 1989 (197% monthly rate) generating economic chaos and a new collapse of the closed-economy approach.

The arrival of Menem to the presidency in May 1989 and the approval of the Convertibility Law, which took effect on April 1st, 1991, marked a new stage in Argentina's economic history.

B. 1991-1998. Economic growth (The Age of Convertibility)

The "Convertibility Plan" implied a change in the relative prices of the economy. The monetary policy was defined by a Peso-Dollar fixed parity that subordinated the national economy to the monetary policy of the U.S. Federal Reserve (Giletta 2005). The new strength of the Peso allowed the payment of the dollarized debts, in particular those of the agricultural sector that was heavily indebted and was able to restore its profitability, overcoming a period characterized by low international prices (Peretti1998).

The key word of this period was "re-primarization", meaning an emphasis on the extractive industries, mainly biomass extraction. Specialization of the Argentinean production system was based mainly on the use of "old" (e.g., agricultural resources) and "new" natural advantages (hydrocarbon and metal resources), and also in the development of consumer-oriented high-income services (property, commercial, financial, education and health) (Heymann 2006).

The increase of the international prices of the exported goods improved the general economic conditions. The supply of exportable goods grew with a significant boost in grain production (between 1997 and 1998 the harvest rose 70%). Exports measured in monetary terms more than doubled between 1993 and 1998 (Heymann 2006). Moreover, in 1996, Argentina approved the use of genetically modified soybeans encouraging the expansion of this crop into newly cultivated land.

C. 1998 to 2002. Financial crisis

In 2001, Argentina´s economy went into a recession with a deep financial crisis and shortage of foreign currency known as the “corralito” (JEC 2003).

In December 2001 the national currency was devaluated. This was caused by the asphyxia of the external financing mechanisms of the convertible Peso. From 1991 to 2003 the external debt rose from US$ 61 billion to 145 billion dollars. Moreover, during these years, the international prices of the main exported products fell, the dollar appreciated and one main trading partner of Argentina, Brazil, had a strong currency devaluation. These years were also characterized by an increasing social unrest and high unemployment rates (Giletta 2005).

As shown in Figure 1, GDP declined over 8% per year between 1998 and 2001 mainly by a domestic demand contraction of -12% (Bugna and Porta 2007).

D. 2003-2009. A new growth phase

This period was marked by a pronounced growth of primary commodity exports. Indeed, the improvement of international commodity prices (Giletta 2005) and the peso devaluation boosted the agricultural and mining sectors.

In this period, Argentina's economy experienced rapid growth. Between 2003 and 2008, the average annual GDP growth was of 8.4%. In 2009, the economy grew only by 0.9%, affected by the international financial crisis (INDEC 2011).

4. Results and discussion

The ‘metabolic profile’ of Argentina is here analyzed on the basis of three material flow indicators: Direct Material Input (DMI), Domestic Material Consumption (DMC) and Physical Trade Balance (PTB). In addition, the terms of trade (TOT) describe the position of a country regarding international trade relations. Dematerialization trends can be compared by indicators of material intensity, which relate material use to population and income (GDP/cap/y) (Fischer-Kowalski and Haberl 2007; Krausmann et al. 2007).

Metabolic profiles are defined by patterns and levels of material use. This concept can be useful to understand the “socio-ecological transitions” from agrarian to industrial regimes with different energy and materials use (Fischer-Kowalski and Haberl 1997, 2007; de Vries and Goudsblom 2002). Argentina´s metabolic profile is very different from that of industrialized countries, although in terms of income per capita the country has scored quite well –it is an upper middle income country (GNI 2010 of 10443 USD) according to the WB.

4.1. Extraction of materials in Argentina

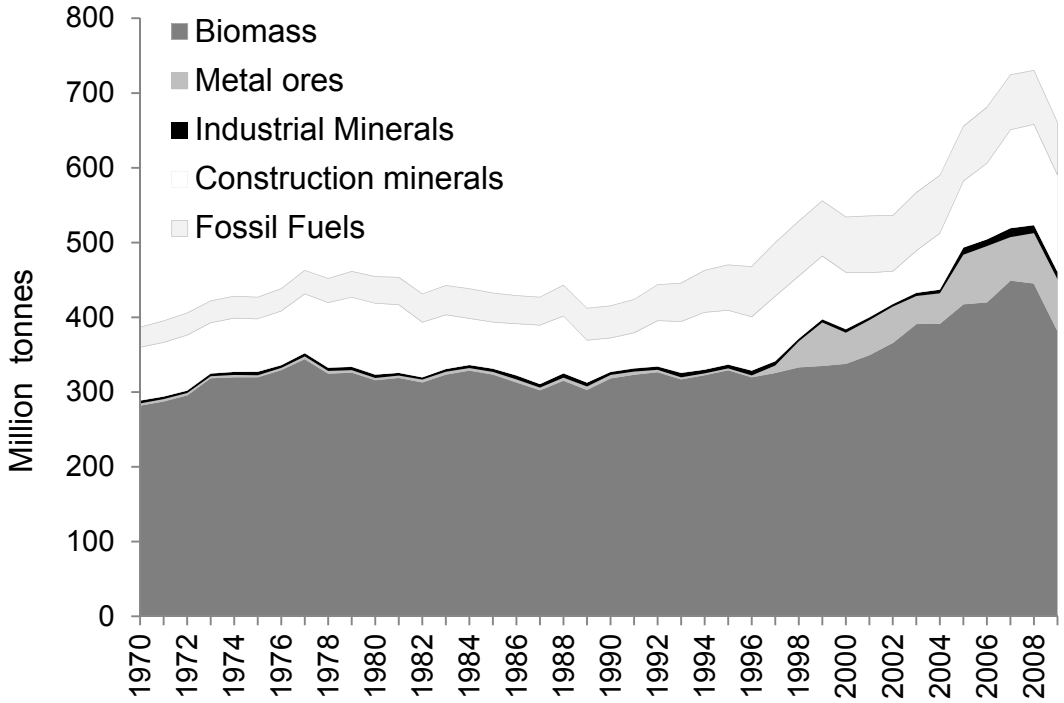
DE considers the materials extracted from the environment within the borders of the economy, providing a picture of the intensity of natural resources extraction. With a territory of 2,736,690 $km^{2,}$ Argentina is the second largest country in South America, over five times larger than Spain, with a large agricultural region (the “Pampas”) with fertile soils and favorable climate and one of the lowest

populations densities of the region (12 habitants per km^2 on average between 1970 and 2009) (WB 2011).

Figure 2 shows DE from 1970 to 2009 by material component. During the period of study DE grew at an annual average rate of 1.46%, barely higher than the population (1.33%) and below the GDP (2.56%) (in US$ constant, base 2000), going from 386 Mt in 1970 to 660 Mt in 2009. The driving force of this increase is not the population growth but the increase in agricultural and mining exports.

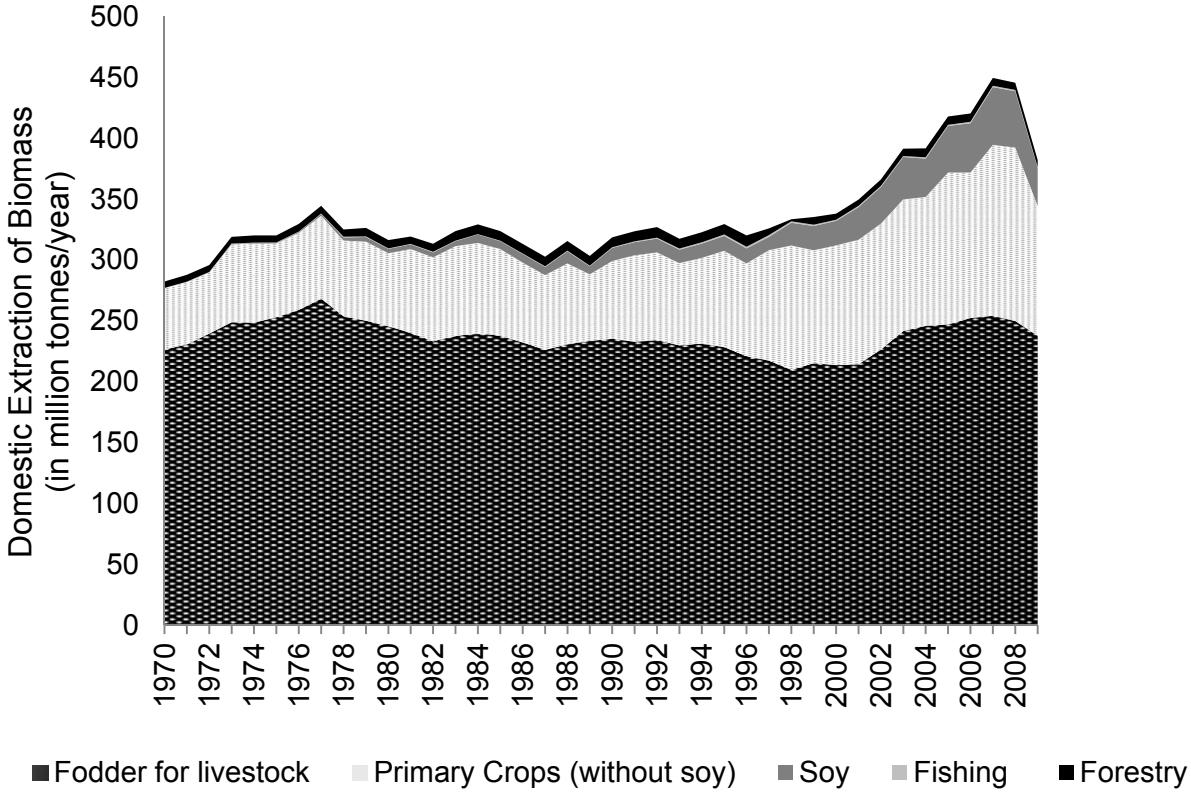
In per capita terms, DE passed from 16.14 in 1970 to 16.46 tons/cap in 2009. Argentina presents higher values of per capita DE than most other economies in the region. For instance, from 1970 to 2007 Colombia had an average DE of 8.3 tons/cap (Vallejo et al. 2011) and Ecuador 7.4 tons/cap (Vallejo 2010). Spain —an economy based on construction activities— had an average per capita DE of 11 tons/cap for the period 1980-2004 (Gonzalez-Martínez et al. 2010), reaching 20 tons/cap at the peak of the building bubble in 2007 (Gonzalez-Martínez et al. submitted).

Figure 2: Domestic extraction of Argentina (1970-2009)



Source: own elaboration based on FAO (2010), MAGyP (2011), SMRA (1993, 2011), USBM (2011) SERA (2000, 2011) and IEA (2010a).

Figure 3: Biomass domestic extraction of Argentina (1970-2009)



Source: own elaboration based on (FAO, 2010) and (MAGyP 2011).

Biomass DE is the predominant flow (70% of DE), it is composed by 71% of fodder for livestock (forage, silage, grazing and by-products), 2% of fishing and forestry biomass and 27% of crops.

From 1997 to 2009, Biomass extraction from primary crops increased from 50 Mt to 137 Mt. In this period, the annual growth rate of primary crops in per capita terms was 2%, higher than the population growth rate. In contrast, per capita biomass DE showed a decreasing trend of -0.46% on average during the period of study. The decline in per capita biomass extraction was due to a reduction in the amount of biomass grazed by livestock, while primary crop production per capita increased.

Soybeans is the predominant flow within the primary crops. According to Pengue (2001), soybeans have displaced other domestically produced crops like cereals, roots, tubers, vegetables and melons. Indeed, during the period of study, these crops have decreased their participation in the primary crops extraction from 44% to 25% for cereals, from 6% to 2% for roots and tubers and from 5% to 2% for vegetables and melons.

From 1970 to 2009 soybeans production passed from 26,000 tonnes to 30.9 Mt. This growth was driven by high international prices for this commodity from the 1990s onwards and by technological factors such as the mechanization of agriculture and the introduction of transgenic soybeans and chemical weeding with glyphosate (Teubal 2006). Since the introduction of genetically modified soybeans in 1996 in Argentina, this crop represents an average of 26% of all primary crops.

The rise in crop production led to the expansion of the agricultural frontier, clearing land and forest, as well as the displacement of indigenous and rural communities. Since the 1990s, Argentina is experiencing one of the largest processes of deforestation in the history of the country (UMSEF 2007a). This entails new issues such as the weakening of food security, as crops are mainly exported and the production of locally consumed crops is decreasing. Growing use of agrochemicals produces water, air and soil pollution, and health impacts on the surrounding populations (Binimelis et al. 2009). The harvested area of soybeans multiplied from 38,000 Ha in 1970 to 18 million Ha in 2009, accounting for more than half of the total agricultural land (MAGyP 2011).

The predominant biomass flow in the economy of Argentina is still grazing, forage, silage and by-products. Nevertheless, a decreasing trend of -1.15% at annual average is observed during the period of study. The expansion of soybean crops diminished the available land for cattle grazing. Millions of hectares that were in agricultural-cattle rotation have been allocated to permanent agriculture, while livestock increasingly depends on feed crops (cereal, soymeal) (PEA2 2010; Santarcángelo and Fal 2009).

Metal ores

Between 1970 and 2009, the DE of ores increased in mass by a factor of 27. This increase was mainly driven by a) improving international prices, b) the approval of laws and regulations aimed at facilitating mining activities and foreign investments during the 1990s and c) the availability of new technologies that made the exploitation of deposits of lower ore quality and metal concentration feasible.

Between 1997 and 1998 ores DE increased from 9.6 Mt to 34.4 Mt. Between 1997 and 2009, the main ores mined were gold, copper, silver and increasingly lithium. The growth in metal ore extraction was driven by the opening of three mining projects since 1997: “Bajo la Alumbrera”, “Cerro de la Vanguardia” and “Salar de Hombre Muerto”. Between 1970 and 1997 per capita ores DE represented on average 0.74% of the DE. Since 1998, it represents on average 9% of DE. Moreover, the exports value of metal ores increased from 150 million dollars in 1990 to 1,200 million in 1999 (Prado 2005). Mining conflicts have become a permanent feature of Argentinean politics since the 2000s (Walter and Martinez Alier 2010; Urkidi and Walter 2011; Svampa and Antonelli 2009).

Fossil Fuels

Regarding fossil fuels, between 1970 and 2009 DE increased by a factor of 3. In 1992-1993 mayor regulatory reforms were promoted, such as the approval of a foreign investment law and the privatization of YPF, the national petroleum company. Licenses to explore and eventually exploit 140 oil concessions for 25 years were released. Natural gas exploitation increased by a factor of 6.31 (ECLAC 1997) during the period of study, showing annual growth rates of 9.9% in 1995 and 13.8% in 1996. Fossil fuels are one of the main inputs of economic activities, and maintained a 10% share of per capita DE.

Construction materials

Per capital annual extraction of construction minerals was on average 3 tons/cap/y representing 17% of per capita DE. In Spain this flow represented 58% between 1980 and 2004 (González-Martínez et al. 2010) and it increased even more until the end of the building boom. Between 1980

and 2009, the sum of construction minerals and industrial minerals related to construction activities increased by a factor of 1.39 (in absolute terms).

Material Flow studies show a close relationship between building materials extraction and economic growth cycles (Weisz et al. 2006; Behrens et al. 2007). The case of Argentina confirms this hypothesis. The deep economic downturns of 1990 and 2001 coincide with the lowest DE of construction minerals. Likewise, economic recovery from 2002 onwards led to the increase of construction activities.

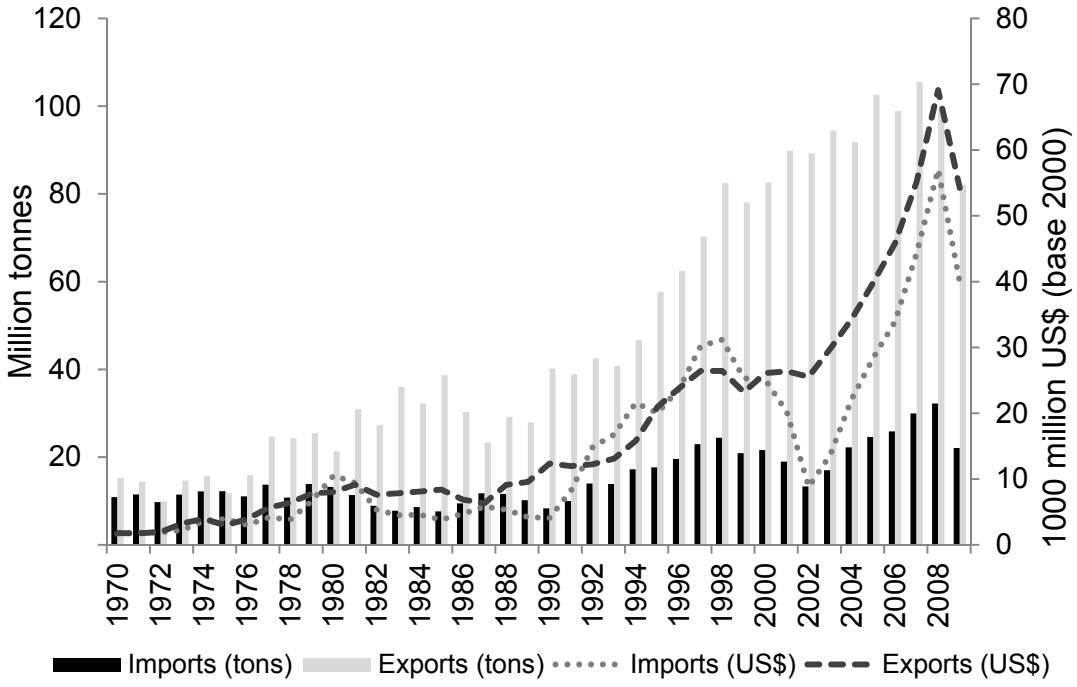
Industrial Minerals

The extraction of industrial minerals has remained relatively low during the period of study. From 1970 to 2009, the flow has fluctuated between 3000 to 12,000 tons, composed by over 90% of clays and salt.

4.2. Imports and exports

Figure 4 presents the evolution of exports and imports in physical terms and their monetary equivalents. Growth of physical exports took place particularly since the mid-1990s, driven by external demand. Between 1970 and 2008, exports grew over six fold. Concerning imports, these remained constant due to import substitution during the 1970s while in the 1980s they physically stagnated due to the economic downturn. Imports grew in the 1990s but fell drastically during the crisis and devaluation of 2001, to grow again rapidly until 2008, being three times larger than in 1970.

Figure 4: Physical and monetary flows from trade of Argentina (1970-2009)

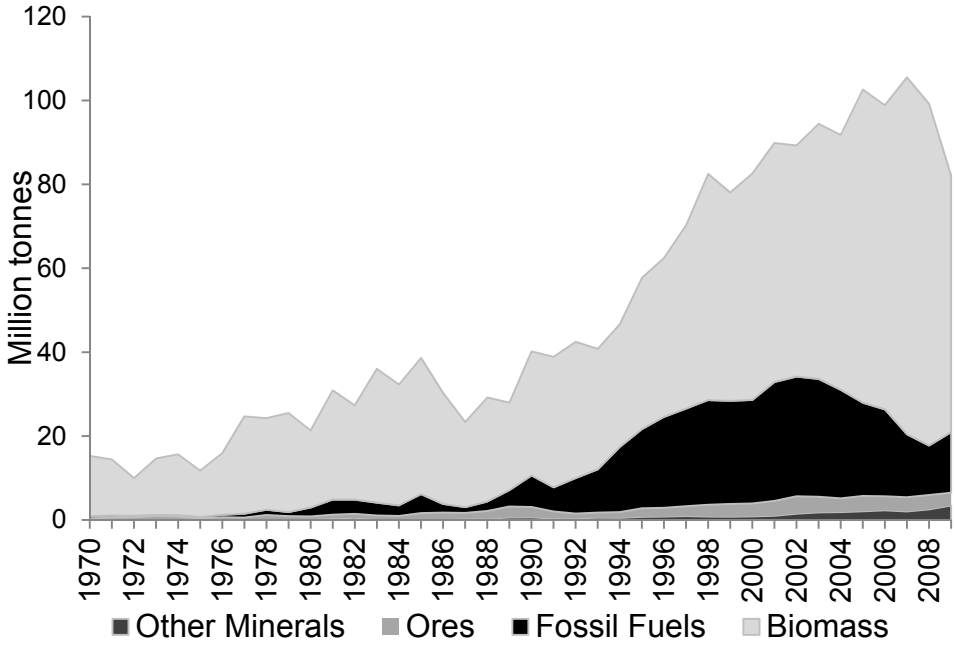


Source: own estimations based on (UNSD 2009).

There is a tight link between trade and monetary policies and the physical response of the economic system. Prior to 1976, trade was characterized by stable features both in terms of weight and value, which ended with the first neoliberal policy package, implemented by the military government once in power in 1976.

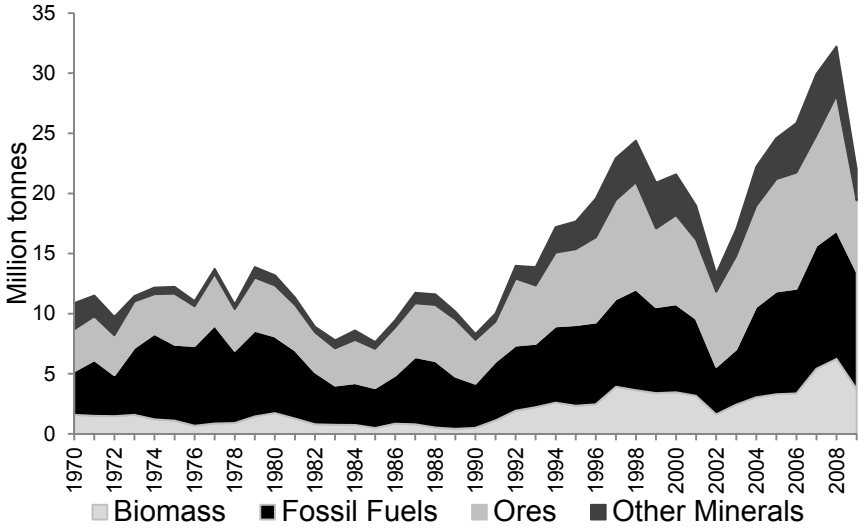
Figure 5 and 6 present the composition of exports and imports in tonnes by main material groups. Notice the different vertical scales.

Figure 5: Physical exports of Argentina (1970-2009)



Source: own estimations based on (UNSD 2009).

Figure 6: Physical imports of Argentina (1970-2009).



Source: own estimations based on (UNSD 2009).

As shown in Figure 5, biomass based products have always been the main exports. From 1993 to 2009, the so-called soy complex (beans, oil, flour and pellets), comprised on average 41% of total weight exported, while manufactures of agricultural products represented an important component of this group. It is important to mention that these products have a low added value (e.g. vegetable oils) (Giletta 2005).

Since the early 1990s, petroleum started to be another major export commodity. In 1989, the government privatized the national petroleum company and liberalized the market, authorizing oil imports and exports (Kozulj 2002). Fossil fuels based products represented about 30% of exports in weight during the 1994-2004 decade. They are now in relative decline due to the fact that Argentina reached its peak oil extraction in 1998. However, further investment could expand known reserves (Araoz et al. 2008).

Concerning imports (Figure 6), fossil fuels and ores have been the predominant flows. Argentina has been very dependent on foreign iron and steel which represented 30% of the cumulative physical imports during 1970-2009, despite an attempt from the government to reduce iron dependency opening an iron mine in 1978 (USBM 2011).

Since the early 1990s, the refining capacity in Argentina has not been enough to meet the increasing domestic demand (Araoz et al. 2008). The remarkable increase in fossil fuels extraction generated a considerable decline of the country oil reserves as new reserves were not added at the rate they were consumed. By year 2008, Argentina became a net importer of oil and its derivatives. This picture could change with the extraction of shale gas in the future.

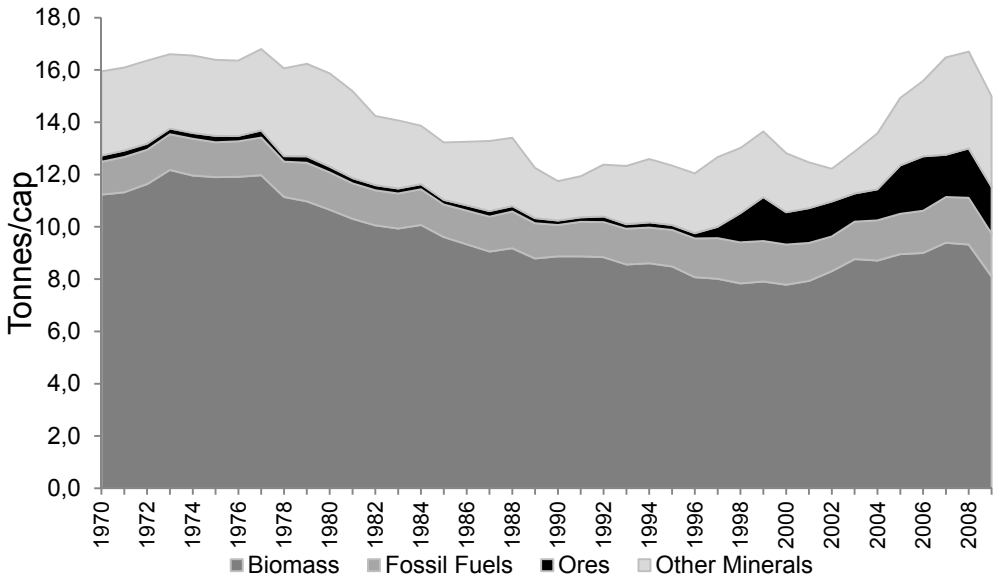
Due to the import and export patterns described above, Argentina has been a net exporter in terms of weight during the whole period. An increasing negative trade balance is observed, 4.4Mt in 1970 and 67Mt in 2008. The PTB deficit of Argentina is one of the highest observed in Latin America, in 2000 it reached 1.65 ton/capita, higher than in Ecuador's and Colombia's which both had 1.3 ton/capita (Vallejo 2010; Vallejo et al. 2011).

4.3. Material input

From 1970 to 2009 Direct Material Input increased from 15 and 19 t/cap/y. Imports grew after 1990 with the fixed parity plan. DE has been the main source of material inputs. Per capita imported materials represented only 2.3% of DMI in 1970 and 3% in 2009. A completely opposite pattern regarding imports is presented by Spain, where per capita imported materials accounted for 23% of the DMI in 1980, increasing to 31% in 2009 (Gonzalez-Martinez, et al. submitted).

4.4. Domestic Material Consumption

Figure 7: Domestic Material Consumption per capita for Argentina (1970-2009)



Source: own estimations based on FAO (2010), MAGyP (2011), SMRA (1993, 2011), USBM (2011) SERA (2000, 2011) and IEA (2010a)

DMC stands for a crucial indicator of the social metabolism in the national territory, providing a good measure –in physical terms– of the intermediate and final consumption of the economy.

Between 1970 and 2009, in Argentina, DMC increased from 382 Mt to 600 Mt with an average annual growth rate of 1.24%. In relation to the population, DMC decreased from 16 to 15 tonnes between 1970 and 2009. Despite this decline, a per capita DMC of 15 tonnes is one of the highest in the region, exceeded only by Chile (Giljum, 2004) and Peru (Silva-Macher 2007), countries characterized by a strong and old mining industry.

Figure 7 shows two trends of the DMC, an initial decline from 1970 to 1990, followed by three consecutive cycles of growth and degrowth. The first must be understood as corresponding to the economic stagnation and the deterioration of GDP per capita during this period, due to political and macroeconomic instability. The second corresponds to the economic growth between 1991 and 1998, the economic decline until 2002 and the rapid growth phase until the 2008 financial crisis.

Biomass

As shown in Figure 7, biomass is the main resource base of this economy, followed by minerals and fossil fuels. Between 1970 and 2009, the share of biomass DMC per capita decreased from 70% to 54%, this could be explained by the increase of soybeans in the DE share, which is mostly exported.

Metal Ores

In contrast, the share of mineral ores consumption per capita has increased since 1997. Between 1970 and 1996 this share was, on average, 1.46% and, between 1997 and 2009, 10%.

Despite the fact that the production of ores has been oriented to export since 1993 (Prado 2005), the significant increase in mineral ores consumption per capita since 1997 can be understood by the processing steps involved in the mining industry. Once such steps are performed, the quantities traded are much smaller than the quantities extracted, generating significant differences between apparent and final consumption (Steinberger et al. 2010). Thus, ore and metal exporting countries such as Argentina tend to have proportionally high levels of apparent consumption of these materials, without actually consuming them.

Construction minerals

Between 1970 and 2009, the share of per capita construction materials increased from 20% to 23%. In the decade of the 70s, the construction sector was characterized by the predominance of the public sector (Coremberg 2000). During this decade, the annual growth rate of per capita construction materials consumption was 1.21%.

Between 1980 and 1990, a significant decline of the construction sector occurred with a negative per capita growth rate of construction materials of -6.67%. With a sustained decline in public investments, this sector depended exclusively on private sector demand. From the early 1990s, in a context of macroeconomic stability, the demand of the construction sector recovered with an average per capita growth rate of building materials of 6.34%. However, given the low activity of the previous decade, it was not until 1998 that the mass flow of building materials reached its previous maximum level (Ruggirello 2011).

After the 1999-2001 crisis period, there was again a rapid increase involving participation of the public sector in housing, roads construction and energy infrastructures (Ruggirello 2011). DMC per capita of construction minerals annual growth rate was 16% between 2003 and 2009 when it reached 3.4 t/cap/y.

Fossil Fuels

Fossil fuels DMC per capita, like the building materials, has remained closely tied to the economic cycles. The share of fossil fuels consumption in total DMC increased from 8% in 1970 to 11% in 2009. Between 1970 and 1990, during the economic stagnation and deterioration of GDP per capita, consumption per capita of fossil fuels remained more or less stable (average annual growth rates of 0.06%). During the economic revival of the 1990s, consumption increased at an annual average rate of 4%. The economic decline that occurred from 1999 to 2002, fostered a 4% fall of consumption. Between 2003 and 2009, there was a 3% annual growth, on average.

If we compare with a European country such as Spain (3.1 t/cap in 2000) (Weisz et al, 2006), Argentinean per capita fossil fuels DMC presents relatively low values, 1.5 t/cap/y on average for the period 1970-2009, peaking at 1.8 t/cap in 2008. Argentina energy matrix (excluding biomass) relies increasingly on natural gas (an efficient energy carrier), up to 50% of the total supply in 2004 (SERA 2004).

4.5. Sociometabolic regimes

According to Krausmann et al. (2008), societies can present different sociometabolic regimes that correspond to a set of impacts on the environment. Krausmann et al. (2008) recognize two main metabolic regimes, namely agrarian and industrial.,

A slow transition from agrarian to industrial regime has been observed for different Latin American countries (Eisenmenger et al. 2007). In Argentina we observe a slow transition towards an industrial regime characterized by a high export surplus in material terms and still by a high relative importance of biomass. During the period of study Argentina sustained a high per capita energy consumption when compared to Latin America. For instance, in 2009, Argentineans consumed 78 GJ per capita and Latin Americans an average of 52 GJ per capita. However, these figures are about half the European Union per capita average (138 GJ/cap in 2009) (WB 2011).

The metabolism of Argentina´s economy shows a large share of biomass production but the significance of this is very different from that in a country like India. Argentina's metabolism is also different from that of densely populated industrial countries (Krausmann et al. 2008). However, the total material flows of Argentina have been high because of the high relative importance of biomass flows. Between 1980 and 2009, the average agriculture added value per worker at constant 2000$ was 8,257$ (WB 2011), higher than the region average of 3,385$ (WB 2011). In addition, the low share of agricultural population is a feature of an industrial regime.

As a primary exporting country, Argentina has a large physical trade deficit and has. suffered from unfavorable terms of trade during long periods of her history. This is in contrast to the physical trade surpluses of industrial countries (such as Spain, other European countries, Japan). Similar DMC per capita goes together with very different economic structures and trade patterns.

In many ways Argentina is a persistent follower of an (often interrupted) "staple growth path" (we refer here to Harold Innis' "staple theory of growth" for Canada). Innis argued that Canada developed as it did because of the nature of its staple commodities, such as fish, fur, lumber, agricultural products and minerals (Innis 1999; Buckley 1958). He was appreciative but also critical of this pattern of economic growth.

The so-called "staple theory of growth" states that export of raw materials can trigger economic growth - while its critics argue that reliance on commodity exports can lead to a development trap because of declining terms of trade and it also depletes natural resources according to what it has been called "the ecological Prebisch thesis" (Perez Rincon 2006).

As regards public policies, one pertinent question is whether Argentina will choose industrialization for the internal market or follow a pattern like that of another staple-export economy such as Australia. Comparing its metabolic profile in per capita terms to that of Australia (Schandl and West 2012), both countries have large physical trade surplus, have a low population density, and a very high degree of urbanization. Argentina has a lower GDP per capita (although rapidly growing in the 2000s). The high levels of biomass (grazing in both countries but also crops in Argentina) and also the moderate levels of building materials per capita are roughly similar in both countries but Australia achieves much higher levels of fossil fuels and metal ores per capita.

4.6. Dematerialization trends

One of the objectives of a MFA is to analyze dematerialization trends. Economies are dematerializing if there is a downshifting in the amount of extracted materials and generated waste. Authors distinguish between strong and weak dematerialization (also referred as absolute and relative decoupling). The first concerns the absolute reduction of extraction and consumption, the second refers to extraction and consumption per unit value (Cleveland and Ruth 1999).

As far as weak dematerialization is concerned, there is a decline of material intensity (DMC/GDP). It went down from 2.8 to 1.6 ton/US$ (constant base 2000) in the 40 years of the study. Regarding strong dematerialization, between 1976 and 1990, during the first economic cycle of recession and macroeconomic instability, absolute DMC decreased at an average annual rate of -0.67%, the same happened between 1999 and 2002 during the economic decline where absolute DMC decreased at an average annual rate of -0.46%. However, there is an overall increase in DMC from 1970 to 2009, from 382 Mt to 600 Mt.

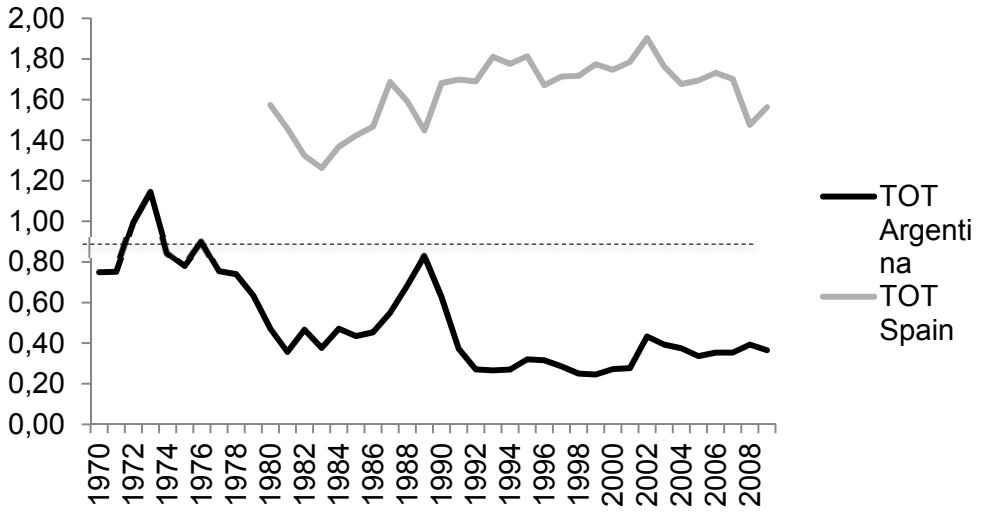
The results obtained for Argentina confirm that there is no evidence on dematerialization regarding overall material use. The only periods of overall absolute dematerialization and relative dematerialization for the case of minerals and fossil fuels were periods of economic recession or decline.

5. Terms of trade and integration in global economy

About six decades ago, the Latin American “structuralist school” introduced a theory about the causes of under development. One such cause was the trend towards deterioration of the terms of trade (TOT) of primary export products. This approach notably defended by Argentinean economist Raul Prebisch rests on the recognition of centre-periphery polarization. According to this theory, the periphery supplies cheap raw materials in competitive markets. Prebisch (1950) observed that the terms of trade for peripheral countries tend to deteriorate because in industrial countries salaries increase in line with productivity.

Comparing Argentina and Spain, we calculate the average value per tonne of imports that can be purchased through the sale of one tonne of exports. In Figure 8, for instance, the value of 0.75 means that one tonne of exports buys only 0.75 tonnes of imports. In this sense, TOT for Argentina are four times lower than those for Spain.

Figure 8: Argentina terms of trade (TOT) (1970-2009) and Spain terms of trade (TOT) (1980-2009).



Source: own estimations based on (UNSD 2009) and Gonzalez-Martinez et al., submitted.

TOT are said to deteriorate if the index decreases, i.e. if the price of exported products tends to decrease compared to that of imported products. TOT for Argentina exhibits a downward trend during the period of study, declining from 0.75 to 0.37.

This is because the technological changes in manufactured goods tend to reduce not only labour inputs but also material intensity. This does not mean however that the total demand for raw materials decreases in general, because of rebound effects and increased social metabolic flows. While technical innovation and increased productivity generates higher profits and wages in the case of manufactured goods, technical progress lowers prices for primary products because these are sold in competitive markets (Prebisch 1950). One exception is the OPEC cartel. But yet, there is no copper cartel or soybean cartel or even a gas cartel.

Moreover, the low price of primary exports does not compensate for the social and environmental costs involved in their extraction and trading (Jorgenson 2009; Rice 2007). In this sense, an ecologically unequal exchange arises (Hornborg 1998, Giljum and Eisenmenger 2004; Muradian and Martinez-Alier 2001). There is an intensified exploitation of natural resources in order to purchase the same basket of imported goods, while environmental liabilities and social costs are not incorporated into the final prices of export goods (Roberts and Parks, 2009). As Hornborg wrote in 1998, world metropolitan areas rely structurally on relatively cheap imports of energy and materials. The North today includes parts of China.

Despite the fact that export prices increased notably in the last ten years, from 297 US$/ton in 1999 to 660 US$/ton in 2009 (at constant prices, base year 2000), Argentina has to pay a large price for imports in terms of exports. For instance in 2009 Argentina was paying for her imports 1212 US$/ton (constant prices, base year 2000). Exports are in volume nearly 4 times larger than imports. Moreover, there are many complaints on the environmental liabilities of soybean, oil and minerals extraction (Pengue 2001; Binimelis et al. 2009; Svampa and Antonelli 2009; Walter and Martinez-Alier 2010).

The industrialization of agricultural exports, the relatively high commodity prices in the 2000s and the fact that Argentina was positioned as a net exporter of fossil fuels for some years after 1990 have not achieved a significant reduction of the gap between the prices of imports/exports.

Conclusions

This study presents information about biophysical aspects of the Argentinean economy using MFA methodology and comparing such results to those of Spain (Gonzalez-Martinez et al. submitted) and other countries. The quantity of materials domestically extracted and consumed in Argentina has grown by 77% and 77.2% respectively during the forty years period of study.

Over the last four decades, external demand was the main driving force for the increasing material extraction of natural resources, as indicated by a near constant DMC per capita and growing DE and exports per capita. The growth of exports since 1970 was mainly based on biomass products. From the late 1990s onwards this pattern changed as fossil fuels (briefly) and metal ores gained importance. Mining projects only consider the production of concentrates and products without refining, so the added value in the extraction of minerals is low. Additionally, despite the fact that manufactures of agricultural origin have increased, the added value remains low.

Therefore, the Argentinean economy presents the same pattern as other Latin American economies. Its terms of trade are totally opposite to those of industrialized economies (such as Spain). Argentina has a large physical trade deficit. Its dependence on exports of commodities increased during the period analyzed. Additionally, it is an economy based on agricultural activities that go hand-by-hand with deforestation, loss of biodiversity, and intensive use of agrochemicals (Binimelis et al. 2009; Pengue 2001). Likewise, open cast mining is also a source of hazardous wastes, which threaten human health and the environment. Such evidence seems to reinforce the ecological Prebisch's thesis.

Krausmann´s typology to analyze sociometabolic transitions (Krausmann et al. 2008) is too general to fit the features and trends of economies like Argentina. Is Argentina agrarian or industrial? It has gone through a transition from an agrarian regime to an industrial economy with an urbanized population but its economy relies on high levels of biomass production and other primary exports. We might conclude that Argentina presents a resource use pattern similar to those countries with an abundance of natural resources, large territories and low population densities such as Australia, but it is far behind Australia in extraction of raw materials per capita. Argentina is highly urbanized and with a relatively high level of energy consumption per capita but its current GDP per capita is only $ 7.665 (US$ in 2009) (WB 2011), certainly one of the largest in Latin America, but far lower than Australia. Its industrial economy is still based on low added value products. It has good perspectives for mining but this attracts strong local opposition for environmental reasons.

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