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Energy Use, CO_2 Emissions and Foreign Trade: An IO approach applied to the Brazilian Case

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Abstract

All goods and services produced in an economy are directly or indirectly associated with energy use and, according to the type of fuel utilized, with CO_2 emissions as well. Foreign trade is a major factor in shaping the industrial structure of countries and, consequently, in affecting countries' energy use and CO_2 emissions. This study evaluates the impacts of foreign trade on the energy use and CO_2 emissions of the Brazilian economy. A commodity-by-industry IO model in hybrid units (energy commodities in physical unit and non-energy commodities in monetary unit) is applied to the Brazilian economy for the years 1985, 1990 and 1995. Total energy- and carbon-intensity coefficients by commodity are derived and applied to the actual trade statistics of Brazil to appraise the energy and carbon embodied in the non-energy foreign commerce of the country. The effects of the trade liberalization on the patterns of energy use and CO_2 emissions of Brazil are discussed.

Keywords: energy; carbon; international trade; hybrid IO Model; Brazil.

Introduction

The debate about the impacts of international trade on energy use and environmental damage (pollution and/or natural resources depletion) is not new. It reached the top concerns on the international agenda in the 70's due to the energy supply crises and it was revived in the 90's by environmental concerns (especially the global and the transboundary ones). The globalization process in course makes this matter more and more evident. The possibility of "carbon leakage" between countries confers to this issue high priority status in the global warming negotiations.[1] Moreover, such discussion is going beyond the technical and official frontier and getting the common citizens on the streets (just remember Seattle in the November, 99 meeting of World Trade Organization). The confluence of these factors (economic, scientific and political pressure) will certainly force a broad debate about this issue sooner than later.

This study aimed at contributing to this debate by analyzing this phenomenon based on the Brazilian case. It focused on the impacts of the foreign commerce of Brazil on its patterns of energy use and CO_2 emissions (carbon emissions, hereafter) in the period of 1985-95. Input-output techniques were applied to estimate total energy and carbon intensity coefficients by commodity for the Brazilian economy in 1985, 1990 and 1995. Such coefficients were utilized to assess the energy and the carbon embodied in the exports and imports of Brazil by multiplying them by the actual foreign commerce statistics of the country. Findings showed that freer trade might not guarantee a better economic use of energy and a cleaner environment. Actually, such a result is in accord with the new position of the World Trade Organization: "*sweeping generalizations are common from both the trade and the environmental community, arguing that trade is either good for the environment, full stop, or bad for the environment, full stop, while the real world linkages are presumably a little bit of both, or a shade of gray*" (The Economist, 1999).

[1] Recent studies raised the concern that greenhouse gas (GHG) emissions policies taken in countries bound by the Kyoto Protocol, the so-called Annex I countries, focusing basically on the reduction of domestic GHG emissions could lead to "carbon leakage". It would happens if Annex I countries reduce their GHG emissions "artificially" by simply stopping producing certain goods (energy- and carbon-intensive goods, most probably) to import them from Non-Annex I countries. In this sense, the effectiveness of GHG emissions Annex I countries' commitments depends on Non-Annex I countries' actions as well, although they are not formally bound by the Kyoto Protocol. For details see, for instance, Wyckoff and Roop (1994).

Background

All goods and services produced in an economy are directly or indirectly associated to energy use and, according to the type of fuel, to carbon emissions. Attempts of tracing all the direct and indirects energy or/environment impacts by process analysis for a broad economic system frequently stops in a huge demand for information and in truncation problems.

In the late 60's, some specialists expanded the use of IO analysis to energy and environmental fields in their works (Daly, 1968; Isard et al., 1968; Ayres and Kneese, 1969; and Leontief, 1970). These studies were benchmarks of an approach that would be further developed by some energy analysts during the 70's and 80's (Wright, 1974; Herendeen, 1974; Bullard and Herendeen, 1975; Bullard, Penner and Pilati, 1978; Costanza, 1981; Hannon et al., 1983; and, Casler and Wilbur, 1984).

The energy/environmental IO approach allows one to trace, throughout an economy, all the direct and indirect energy/environmental impacts of changes in the final demand. It means that one may attribute all the impacts to the very ultimate source of its demand. By combining energy and environmental physical data and monetary IO tables, one gets a consistent and systematic tool to evaluate impacts of economic changes on energy use and on the environment. Different impacts may be considered, such as energy use, atmospheric emissions, solid wastes, water effluents, depletion of natural resources, etc. The use of this technique has provided important insights to guide energy and environmental policies in several countries (see, for instance: Darmstader, Dunkerley and Alterman, 1977; Östblom, 1982; Roop, 1987a; Gowdy and Miller, 1987; US DOE, 1989; US Congress, 1990; and, Casler and Blair, 1997).

Particularly, some studies have addressed the role of international trade in determining energy use and environmental damage (Wright, 1974; Fieleke; 1975; Bullard and Herendeen, 1975; Herendeen and Bullard, 1976; Herendeen, 1978; Stephenson and Saha, 1980; Strout, 1985; Roop, 1987b; US DOE, 1989; US Congress, 1990; Han and Lakshmanan, 1994; Wyckoff and Roop, 1994; Schaeffer and Sá; 1996; Young, 1996; Khrushch, 1996; Östblom, 1998; Lezen, 1998; Chang and Lin, 1998; Wier, 1998; Lange, 1998; and, Proops et al., 1999). The main concern of these international trade oriented studies has been to evaluate how foreign commerce affects the domestic demand for energy and how it impacts the environment.

Energy and pollutants embodied in international trade have been assessed for particular countries as well as for the world economy (foreign commerce worldwide). Not surprisingly, a general conclusion has been that the opener the economy the larger the impact foreign commerce has on a country's figures. Notwithstanding, the mix of the products exported and imported and the technical efficiency in processing the products and their inputs might definitely affect the energy and pollutants flows towards and from the country. All those trade-oriented studies have pointed out that imports and exports could not be neglected for a relatively open economy; otherwise, energy and environmental figures might be badly distorted for this economy.[2] Moreover, some studies have presented evidences to support that international trade should be considered in the global warming agreements to avoid "carbon leakage" to Non-Annex I countries (Wyckoff and Roop, 1994; Khrushch, 1996; Schaeffer and Sá, 1996; and Lezen, 1998).[3]

Basically, the role played by foreign commerce seems to be very significant in affecting energy use and environmental damage of countries in particular, as well as of the world as a whole. In addition, such a role might be enhanced in the future because of the globalization process worldwide. So far, however, a case-by-case approach is still necessary to reveal whether or not particular policies should be designed to deal with this problem. This work is part of the Federal University of Rio de Janeiro efforts to further analyze

[2] For instance, Stephenson and Saha (1980) appraised that the energy embodied in the imports of New Zealand reached 47% of the total energy use of this country in 1976, while the energy embodied in its exports represented 26% of the New Zealand's total energy use. That is the most impressive case reported in the literature reviewed.

[3] According to Wyckoff and Roop (1994), for instance, about 13%, on average, of the total carbon emissions of six OECD countries (Canada, France, Germany, Japan, the UK and the USA) was embodied in manufactured imports in the mid-1980's. The authors pointed out that this amount of carbon (300 millions tons of carbon) was equivalent to one-fifth of the carbon emitted annually by the USA, it exceeded the level generated by Japan and it was more than double the amount emitted by France and Canada.

the evolution of energy and pollutants embodied in foreign commerce of Brazil and aims at providing backgrounds to the Brazilian policy-makers.[4] In particular, this study focuses on the evolution of energy and Carbon Dioxide (CO_2) embodied in the international trade of Brazil in the 1985-95 period.

Methodology, Assumptions and Data Preparation

The fundamental methodological principle to assess the energy and carbon embodied in foreign commerce is to multiply total energy and carbon intensity coefficients by foreign commerce figures. Accordingly, the first step to appraise the energy and carbon embodied in the international trade of Brazil is to estimate total energy and carbon coefficients for the Brazilian economy.

This study uses the so-called input-output model in hybrid units (hybrid units model hereafter) in a commodity-by-industry approach to estimate total energy and carbon coefficients for the Brazilian economy. Bullard and Herendeen (1975) developed the hybrid units model in order to overcome shortcomings and limitations associated to the usage of the direct coefficient over the Leontief inverse matrix formulation (direct coefficient formulation hereafter).[5]

The basic idea of the hybrid units model is to substitute energy rows expressed in physical units for energy rows valued in monetary terms in the IO table, before recalculating the Leontief inverse based in the new flows. In this new IO table, flows are expressed in hybrid units: energy commodities in physical units and non-energy commodities in monetary units. The energy rows in the matrix of technical coefficients present the direct energy-intensity coefficients for each commodity, while the energy rows in the Leontief inverse matrix provide the total energy-intensity coefficients for each commodity (direct plus indirect energy requirements per unit of good or service delivered to final demand). Take in consideration that energy data can be expressed in carbon figures by applying the well-known conversion factors provided by the IPCC (1996). Thus, for concision, the derivation of the model below will refer only to energy units, but the same may be considered for carbon emissions.

By considering the commodity balance equation in hybrid units (energy commodities in physical units and non-energy commodities in monetary value units), one gets the commodities use flows:[6]

$$G = Ui+H \qquad (1)$$

Where:

U [$=u_{ij}$] is the use matrix that shows the amount of commodity "i" required by industry "j";
H [$=h_i$] is the final demand vector by commodity that displays the amount of commodity "i" claimed by the final demand;
G [$=g_i$] is the total commodity output vector that provides the total amount of commodity "i" demanded or produced (in equilibrium) by the economy;
i is the unity-column vector that is a vector where all elements are equal to the unity ($i_{i1}=1$).

Accepting the basic assumption of fixed proportions in the production function, one can appraise the technical coefficient matrix B [$b_{ij} = u_{ij}/O_j$]:

$$B = U (\hat{O})^{-1} \qquad (2)$$

[4] Schaeffer and Sá (1996), Young (1996) and Machado and Schaeffer (1997) were first steps in this direction.
[5] The most serious problem in using the direct coefficient formulation is the violation of the energy conservation law (primary energy = secondary energy + energy losses). It happens unless uniform energy prices are observed in all industries. That is a strong constraint that is not usually verified in reality. Another problem is that it introduces errors in the estimations when simulating new final demand vectors significantly different from the base-year final demand vector. For details see: Bullard and Herendeen (1975), Miller and Blair (1985) and Casler and Blair (1997).

[6] Such derivation may be found in details, and with examples, in Miller and Blair (1985). See also Hannon et al. (1983) and Casler and Wilbur (1984).

$\hat{O}$ is the total output **by industry** vector diagonalized (the “hat” means the vector is diagonalized – Oj elements in the main diagonal and zero anywhere else).

However, in a hybrid units model, the total output **by industry** vector (O) cannot be derived from the addition of the use matrix (U) and the value added by industry vector (W). It happens because commodities (rows) in the use matrix are expressed in different units, resulting that sum across rows is not possible. To assess the total output **by industry** vector (O) one must use the make matrix.

The make matrix (V) presents the total amount of commodity “j” produced by industry “i”. This matrix allows one to know the mix of commodities produced by each industry (by reading the rows). Since the make matrix (V) is also defined in hybrids units (energy commodities in physical units and non-energy commodities in monetary value units), here, again, sum across columns is impossible. However, summing across make matrix rows is possible. So, in accepting that the total output by industries is produced based in a commodity inputs fixed proportions (the so-called industry-based technology assumption), one can get the market-share matrix D [$d_{ij} = v_{ij}/G_j$]:

$$D = V\,(\hat{G})^{-1} \qquad (3)$$

Where V is the make matrix, $\hat{G}$ is the total commodity output vector diagonalized and D the market-share matrix that presents the market-share of industry “i” in producing the commodity “j”. Actually, the market-share matrix is a transfer operator matrix that allows one to convert commodity in industry figures and otherwise by pre- or post-multiplying it by the relevant vector or matrix to be converted.

Thus, one can find the total output by industry vector (O) in hybrid units by pre-multiplying the market-share matrix (D), calculated in hybrid units, by the total commodity output vector (G) also in hybrid units:

$$O = DG$$

From this point on, one can return to equation (2), calculate the technical coefficient matrix B in hybrid units and rewrite (1) as:

$$G = BDG+H \qquad (4)$$

One has to be aware that in post-multiplying B by D, one gets a commodity-by-commodity matrix of technical coefficients in order to operate the model (since G and H are, respectively, total output and final demand by commodity vectors of nx1 dimension).

Finally, one can rearrange and solve equation (4) to:

$$G = (I-BD)^{-1}\,H \qquad (5)$$

Where G is total commodity output, $(I-BD)^{-1}$ is the commodity-by-commodity Leontief inverse matrix and H is the commodity final demand, all in hybrid units.

As mentioned before, the energy rows in the matrix of technical coefficients present the direct energy-intensity coefficients by commodity, while the energy rows in the Leontief inverse matrix provide the total energy-intensity coefficients by commodity. In order to get only these vectors one should assess the matrix product $\hat{J}\,(\hat{G})^{-1}$, where J is a vector presenting 0 (zero) for non-energy commodity rows and the total energy commodity J_k in physical units for energy commodity rows, and G is, once again, the total commodity output vector. The result of such matrix product is a matrix of ones and zeros, the ones identifying the locations of energy commodity rows. So, one can, easily, assess the direct energy-intensity coefficients and the total energy-intensity coefficients in hybrid units (energy unit/energy unit for energy commodities and energy unit/monetary value unit for non-energy commodities) by applying the following equations, respectively:

$$\delta = \hat{J}\,(\hat{G})^{-1}\,BD \qquad (6)$$

$$\alpha = \hat{J} (\hat{G})^{-1} (I-BD)^{-1} \qquad (7)$$

Considering a closed economy, a consistency proof might be placed by testing the equation $J = \alpha H$, where total energy-intensity (α) and commodity final demand (H) vectors are expressed in hybrid units and the total energy commodity (J) is presented in physical units. The vector product αH must equal the total energy commodity (J), which is an input data in a hybrid formulation (in energy or carbon units).

Verified the consistency of the model, one might use these coefficients to assess the energy embodied in the foreign commerce, as mentioned before.

The assessment of the energy embodied in the exports is quite obvious, since exports (X) are a part or a component of the total final demand (H). So, if one pre-multiplying the total energy-intensity (α) by the exports (X) vector, one can assess the total energy embodied in exports (J_x), as described by the following equation:

$$J_x = \alpha X \qquad (8)$$

Consider, though, that in the present study the exports vector was constructed based on actual export statistics rather than taken from the input-output tables (both vectors might differ since input-output tables are, frequently, adjusted to express an economy in equilibrium).

Regarding imports, it depends on the aim of the study: a particular country or international energy flow analyses. In this study, the idea was to appraise the energy "saved" by Brazil by importing non-energy goods. So, the proper vector of total energy-intensity coefficients to be used in assessing the energy embodied in imports (J_M) is the same estimated for final demand (and also used for exports).[7]

$$J_M = \alpha M \qquad (9)$$

Here, once again, imports vector was constructed based on actual imports statistics rather than taken from the input-output tables.

Assumptions and Data Preparation

Basically, three sets of data were required to assess the energy and the carbon embodied in the international trade of Brazil: IO tables, energy and foreign commerce statistics. They were provided respectively by IBGE (The Brazilian Institute of Geography and Statistics), MME (the Brazilian Ministry of Mining and Energy) and BACEN (Central Bank of Brazil). Three years were selected for the analysis: 1985, 1990 and 1995. IO tables, energy and foreign commerce statistics were available for these years. The years selected seem to be key years to analyze the effects of a freer trade environment on the energy and carbon embodied in the international trade of Brazil. In 1985, the Brazilian economy was relatively closed. In 1990, a new Government formally started a liberalization process in the Brazilian economy. In 1995, most of the liberalization measures were already implemented (Bonelli, Veiga and Brito, 1997; Cavalcanti and Ribeiro, 1998; and, Pereira and Carvalho, 1988).

However, the industrial classification systems of the IO tables, energy and foreign commerce statistics were not the same. In this sense, the first task of this work was to make these three systems compatible. It involved a detailed analysis of the three classification systems and the definition of an industrial classification system that satisfied the basic needs of the present study.

[7] Otherwise, a new total energy-intensity coefficients vector should be estimated based on input-output tables of the exporter countries (from where imports of the relevant country come from). Obviously, it is operationally impossible to cover all the exporter countries. So one might select a "typical" exporter country or calculate an average of the coefficients based on some major exporter countries.

The industrial classification system of the energy statistics was used as a base for defining the classification of the present study.[8] This decision was made based on the fact that the industrial classification of the energy statistics is the most aggregated one and it is not possible to disaggregate it further in a reliable manner (it is important to keep the physical data unspoiled in the hybrid unit model). Accordingly, the industrial classification systems of IO tables and the foreign commerce statistics were adjusted to meet the industrial classification system of the energy statistics. After such adjustments, the new Brazilian IO tables displayed 19 commodities and 14 industries (19x14 dimension).

In addition, some adjustments were also needed in the energy data provided by the MME in the Brazilian Energy Balance (BEB). Hydroelectricity data was corrected based on its caloric equivalent (860 kcal = 1 kWh) and fuel data was adjusted to express their low heating value (LHV), as suggested by international conventions (IPCC, 1996).

Primary energy was used as a proxy for the total energy requirements. However, to avoid an overburden of the energy industry where the transformation of energy carriers leads to large losses, this study distributed the total primary energy through industries based on their share in the final energy use by source. In other words, energy transformation and distribution losses were attributed to end-use industries rather than entirely to the energy industries. For instance, rather than attribute all the firewood used to produce charcoal to the energy industry, this study distributed the firewood used for charcoal production among the end-users of charcoal. This procedure implied that only primary energy commodities in the IO tables were replaced by physical flows, while secondary energy commodities were ignored to avoid double counting.

Imported energy commodities were added to domestic energy commodities in order to account for all the energy and carbon requirements of the economy. In case of imports of secondary sources (Oil Products, for instance), the primary equivalent of each source was added to the relevant commodity row (Crude Oil and Natural Gas). The primary equivalent of imported secondary energy commodities was distributed by the end-users keeping the same structure of the total final use for each source.

Finally, non-energy use was subtracted from energy figures in order to consider only sources actually required for energy use.

After adjusting primary energy figures, conversion factors from primary energy to carbon were applied to calculate the carbon emission. Conversion factors from primary energy to carbon were obtained from IPCC (1996) and Schechtman, Szklo and Salas (1999), and then weighted by the share of the respective source in the energy commodity as defined in the IO Model. Also, this study calculated net carbon emissions, meaning that the whole carbon cycle was considered, abating the carbon that was absorbed on the growth period of the biomass (firewood and Sugar Cane Energy Products).

Findings

Table 1 presents the total energy and carbon intensity coefficients by commodity for the Brazilian economy in 1985, 1990 and 1995. Total energy intensity coefficients are expressed in MJ/US$-95 (US dollars in constant prices of 1995), while total carbon intensity coefficients are displayed in g C/US$-95.

All the commodity groups in the Brazilian economy, except for the Other Industrial Products, showed upward trends in their respective energy intensity coefficients from 1985 to 1995. The largest raises were verified on Chemicals, Mining and Quarrying, Textile and Clothing and Non-Ferrous Metals which increased, respectively, by 104 percent, 54 percent, 43 percent and 42 percent from 1985 to 1995. In absolute terms, Iron and Steel showed the highest energy intensity coefficients in the whole period: 46.2 MJ/US$-95 (1985), 56.5 MJ/US$-95 (1990), 61.0 MJ/US$-95 (1995). In 1995, the coefficient of Iron and

[8] Only two changes were made: "Pig Iron and Steel" and "Ferro-Alloys" were aggregated in "Iron and Steel"; and "Cement", "Ceramics" and "Other Non-Metallic Minerals" were aggregated in Non-Metallic Minerals. These changes were necessary to avoid additional and unreliable modifications on the IO tables and foreign commerce data.

Steel was 80% higher than the second highest (Chemicals) and more than twice as much as the third and the fourth highest (Pulp and Paper and Non-Metallic Minerals, respectively). The smallest energy intensive coefficients were registered in the Textile and Clothing (5.4, 6.0 and 7.7 MJ/US$-95), Agriculture and Livestock (7.3, 7.8 and 8.4 MJ/US$-95) and Other Industrial Products (10.4, 9.9 and 8.4 MJ/US$-95). Nevertheless, the only group of commodity that presented a downward trend was the Other Industrial Products, as mentioned before. Thereby, in 1995, the energy intensity coefficient of the other industrial products equaled the coefficient of the Agriculture and Livestock, so far the second lowest. It also got closer to the Textile and Clothing's energy intensity coefficient, the smallest one.

Table 1 - Total Energy and Carbon Intensity by Commodity in Brazil, 1985-95

	Energy (MJ/US$-95)			Carbon (g C/US$-95)		
	1985	1990	1995	1985	1990	1995
Agriculture and livestock	7.3	7.8	8.4	129	133	131
Mining and quarrying (except fuel)	13.9	16.4	21.4	221	244	305
Food and beverages	11.1	11.5	13.3	142	145	146
Textile and clothing	5.4	6.0	7.7	76	81	93
Pulp and paper	21.8	21.6	28.1	363	348	449
Iron and Steel	46.2	56.5	61.0	998	1213	1328
Non-ferrous metals and other metallurgical products	16.8	21.2	23.8	289	352	392
Non-metallic minerals	26.2	24.1	27.5	540	467	518
Chemicals	16.9	17.0	34.3	238	240	424
Other industrial products	10.4	9.9	8.4	165	155	129
Exports' Average (ex)	13.9	16.6	17.8	239.1	288.1	297.7
Imports' Average (em)	12.9	12.9	14.1	207.1	206.0	207.1
Terms of Trade (ex/em)	1.08	1.28	1.27	1.15	1.40	1.44

Source: Based on MME (1999), IBGE (1995 and 1999), Haguenauer, Markwald and Pourchet (1998) and BACEN (1986, 1991 and 1997).
Note: US$-95 = US dollars in constant prices of 1995.

Further studies by commodity group are necessary to reveal the actual reasons for such upward trends. It is very unlikely that all commodities, but Other Industrial Products, were produced in less energy efficiently in this period of liberalization process. Some possible explanations for these trends are depreciation of the monetary value of output, intra-groups changes towards a more energy-intensive commodity mix, inter-fuel substitution towards less energy efficient sources and technical obsolescence. The first two explanations seem to be important in the case of Iron and Steel, Non-Ferrous Metals, Pulp and Paper and Chemicals (Rosa and Tolmasquim, 1993; and Machado, 1996). In the Non-Metallic Minerals, two facts seem to explain the trends of this group (Rosa and Tolmasquim, 1993; and Machado, 1996). First, the substitution of fossil fuel for electricity (more than 90% comes from hydropower in Brazil) in the 90's, reversing the use of electricity for thermal processes that was encouraged by the Government in the early 80's (to save imported oil). Second, the absence of expanding productive capacity investments in this period, leading to the use of technical obsolescent facilities during a period of demand increases. In traditional groups - such as Agriculture and Livestock, Food and Beverages and Textile and Clothing -, the upward trends of the energy intensity coefficient may be explained by the proper technical evolution that replaces labor by capital (machines and electrical equipment), leading to higher energy requirements in their producing processes. Nevertheless, such explanation attempts should not substitute further studies about these upward trends of energy intensity coefficients in Brazil.

Regarding carbon, results were very similar. Most of the groups also showed upward trends in the 1985-95 period, although these trends were relatively smoother than the ones of energy intensity coefficients. It reveals changes towards less carbon-intensive energy sources, such as electricity, charcoal, sugar-cane energy products and other renewable primary sources (black liquor and vegetable residues, for instance). Exceptions were Other Industrial Products and Non-Metallic Minerals, that presented downward trends in the period considered (22 and 4 percent, respectively). Here, again, Iron and Steel also register the highest carbon-intensive coefficients in all years: 998 g C/US$-95 (1985), 1213 g C/US$-95 (1990) and 1328 g

C/US$-95 (1995). It is more than twice as much as the carbon intensity of Non-Metallic Minerals (the second highest). As for energy, further studies are necessary to understand better such trends.

The last three rows of Table 1 shows, respectively, the average coefficients of the exports, the average of the imports and the terms of trade in energy and carbon of the Brazilian trade accounts. One can verify that the terms of trade for both energy and carbon were higher than the unity for all the years. It means that each dollar earned with exports embodied more volumes of energy and carbon than each dollar expended with imports in the 1985-95 period. In other words, in an equilibrium situation (net balance of trade accounts equal to zero), Brazil would have been a net exporter of energy and carbon embodied in non-energy commodities. In addition, from 1985 to 1995 the exports of Brazil became, in average, progressively more energy and carbon intensive than its imports.

Table 2 shows the Brazilian trade accounts of non-energy commodities in millions of dollars in constant prices of 1995 for the 1985-95 period.

Table 2 – Non-Energy Commodities Trade Account of Brazil, 1985-95 (Millions of US$-95)

	Exports			Imports		
	1985	1990	1995	1985	1990	1995
Agriculture and livestock	6683	4040	4637	1406	1914	4125
Mining and quarrying (except fuel)	2589	3249	2857	190	146	194
Food and beverages	6659	6123	8285	96	482	1054
Textile and clothing	1001	938	1033	23	142	1346
Pulp and paper	848	1497	2821	192	459	1371
Iron and steel	3068	3660	4291	225	434	699
Non-ferrous metals and other metals	443	1354	1272	328	481	1096
Non-metallic minerals	204	307	456	47	86	75
Chemicals	1139	1278	1519	2056	3397	6302
Other industrial products	12525	12840	17983	4736	10296	28014
Non-energy total	35160	35285	45153	9298	17838	44276

Source: BACEN (1986, 1991 and 1997).
Note: US$-95 = US dollars in constant prices of 1995. It excludes Special Transactions.

From Table 2 one can verify that the share of energy-intensive commodities (Pulp and Paper, Iron and Steel, Non-Ferrous Metals, Non-Metallic Minerals and Chemicals) in exports increased from 16.2% of the non-energy total in 1985 to 22.9% in 1995, while the share of energy-intensive commodities in imports dropped from 30.6% to 21.6% in the same period. These figures revealed a change in the trade specialization of Brazil in this period. This fact partially supports concerns about the specialization of the developing countries in “environment-unfriendly” activities in the future. Another point to be emphasized is the effect of the trade liberalization on the Brazilian imports. From 1985 to 1995, imports of non-energy commodities increased in 376%, while exports of non-energy commodities grew only 28% in the same period.

By applying the energy and carbon intensity coefficients (Table 1) to the foreign trade statistics of Brazil (Table 2), it is possible to estimate the energy and the carbon embodied in the international trade of Brazil.

Table 3 presents the energy and the carbon embodied in the exports and in the imports of Brazil by commodities in 1985, 1990 and 1995.

Table 3 - Energy and Carbon Embodied in Non-Energy Trade Accounts of Brazil by Commodity, 1985-1995

	Exports						Imports					
	Energy (PJ)			Carbon (1000 t C)			Energy (PJ)			Carbon (1000 t C)		
	1985	1990	1995	1985	1990	1995	1985	1990	1995	1985	1990	1995
Agriculture and livestock	49	32	39	864	537	609	10	15	34	182	254	542
Mining and quarrying (except fuel)	36	53	61	573	792	870	3	2	4	42	36	59
Food and beverages	74	70	110	944	890	1207	1	6	14	14	70	154
Textile and clothing	5	6	8	76	76	96	0	1	10	2	11	126
Pulp and paper	18	32	79	308	522	1267	4	10	39	70	160	616
Iron and Steel	142	207	262	3062	4439	5699	10	25	43	224	527	928
Non-ferrous metals and other metals	7	29	30	128	477	498	6	10	26	95	169	429
Non-metallic minerals	5	7	13	110	143	236	1	2	2	25	40	39
Chemicals	19	22	52	271	306	644	35	58	216	489	814	2674
Other industrial products	131	128	150	2071	1986	2312	49	102	234	783	1592	3602
Non-Energy Total	487	586	804	8406	10167	13440	119	231	623	1925	3674	9169

Source: Based on MME (1999), IBGE (1995 and 1999), Haguenauer, Markwald and Pourchet (1998) and BACEN (1986, 1991 and 1997).

Table 3 shows that both energy and carbon embodied in exports and imports increased in the 1985-95 period. However, it easy to see that both energy and carbon embodied in imports grew faster than in exports. Basically, it can be explained by the growth of imports vis-a-vis exports (both measured in monetary values); i.e., the scale effect. The net energy and carbon embodied balance still remained positive for Brazil, although the difference shrank along the period. The net energy balance was reduced from 368 PJ in 1985 to 181 PJ in 1995. It meant 6.5% and 2.7% of the total primary energy use of Brazil in 1985 and 1995, respectively. On the other hand, the net carbon balance fell from 6481 thousands of t C in 1985 to 4272 thousands of t C in 1995. For the same period, the net carbon balance presented a smoother drop than the net energy balance. The net carbon balance in the Brazilian trade accounts represented 7.1% and 4.3% of the total carbon emission of Brazil in 1985 and 1995, respectively.

The keys groups of commodities for the net energy balance result were Iron and Steel, Chemicals, Food and Beverage and Other Industrial Products. Iron and Steel and Food and Beverage impacted positively the net balance, while Chemical and Other Industrial Products (only in 1995) affected it negatively. For the net carbon balance, the key groups of commodities were Iron and Steel, Chemical, Food and Beverage, Other Industrial Products, Mining and Quarrying and Pulp and Paper. Iron and Steel, Food and Beverage, Mining and Quarrying and Pulp and Paper impacted it positively, while Chemical and Other Industrial Products (only in 1995) affected it negatively.

Conclusions and Policy Implications

This study aimed at contributing to the debate about the impacts of international trade on resource use and environmental damage by analyzing the Brazilian case for energy use and carbon emissions in the 1985-95 period. During this period, the Brazilian economy started a liberalization process. In this sense, it was a good opportunity to evaluate the influence of a progressive freer trade environment on the energy use and carbon emissions.

A commodity-by-industry input-output model in hybrid units was constructed to estimate total energy and carbon intensity coefficients by commodity for the Brazilian economy in 1985, 1990 and 1995. Then, these coefficients were applied to the actual foreign statistics of Brazil to calculate the energy and the carbon embodied in the country's non-energy commodity exports and imports for the same years. Findings showed that Brazil registered positive net energy and carbon balances in all years considered, although the difference between energy and carbon embodied in exports and imports shrank from 1985 to 1995. In other words, Brazil was a net exporter of energy and carbon in the 1985-95 period. The main reason to such a result seemed to be the proper evolution of the trade accounts of Brazil in the period, since imports grew much faster than exports in this period. The first consequence of the trade liberalization in Brazil was to promote a huge growth in imports, reducing the very net balance in monetary value. Actually, the economic stabilization policy of the Government relied on imports to stabilize domestic prices and on foreign capital to finance the public deficit that led to an overvaluation of the Brazilian currency, reinforcing the imports and hampering the exports.

However, after 1999 financial crisis in Brazil, it is unlikely that such a trend (imports growing faster than exports) will remain for long. Otherwise, according to the current Government speech the huge current accounts deficit (US$ 35 billions in 1998 and US$ 24 billions in 1999) will be paid by a trade account surplus (mainly by stimulating exports). Considering the tendency of terms of trade in energy and carbon for Brazil to be higher than the unity (exports are more energy and carbon-intensive than imports, in average), *ceteris paribus*, the larger the surplus in the trade account the larger the positive net balance in energy and carbon. In this sense, it is likely that in the next years the net energy and carbon balance will spread up again, unless corporate measures aiming at reducing the energy and carbon intensity of commodities would be implemented. Nevertheless, even under a liberalization process, it was not the case in the last years in Brazil. Accordingly, particular policies seem to be needed to deal with this problem.

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