PATTERNS OF ENERGY USE IN THE BRAZILIAN ECONOMY: CAN THE PROFILE OF BRAZILIAN EXPORTS DETERMINE THE FUTURE ENERGY EFFICIENCY OF ITS INDUSTRY?

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ABSTRACT

This study examines the integration of the Brazilian economy in the global economy as a determining factor for the energy efficiency of its industry. Depending upon the profile of a country's exports (i.e., depending upon the share of energy-intensive exports out of total exports), different quantities of energy are required to produce the country's exported goods, which may counterbalance efforts made elsewhere to improve the overall energy efficiency of the country's industry.

Different scenarios for the energy embodied in the industrial exports of Brazil are considered for the period 1995-2015. These scenarios are a combination of different shares of energy-intensive goods in the total exports of the country with different assumptions for gains obtained in industrial energy efficiency over time. For all scenarios the same fundamental hypothesis of liberalization of commerce and economic growth are assumed.

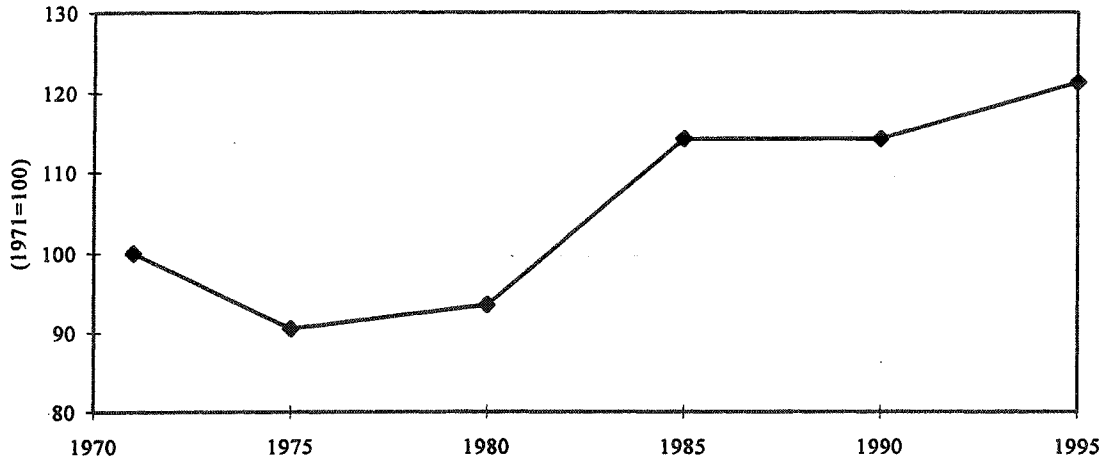
Results for the year 2015 show that the total energy embodied in industrial exports varies from 1,413 PJ to 2,491 PJ, and the total industrial use of energy varies from 3,858 PJ to 6,153 PJ, depending upon the assumptions made. This is equivalent to an average industrial energy intensity variation ranging from 13.8 MJ to 22.0 MJ per US$-1985.

We conclude that any policy aimed at improving Brazil's overall industrial energy efficiency should concentrate not only on the reduction of the energy intensity of particular industrial sectors, but also (and, perhaps, more importantly) on rethinking the very strategy for the integration of the country's economy in the global market in the future, with respect to the share of energy-intensive goods out of total exports. The focus is not incidental, for the ongoing structural changes in Brazilian exports alone may come to offset any efficiency improvements achieved by the national industry as a whole.

INTRODUCTION

In the course of the 70s and 80s, the economy of Brazil underwent a period of consolidation of its Industry, implementing the major base sectors of the Manufacturing Sector (Iron and Steel, Non-ferrous Metals, Basic and Intermediate Petrochemicals, and Pulp and Paper industries) on a large-scale. [1, 2, 3] This phase of the industrialization process characterizes and determines a mature industrial mass production stage and, ultimately, the very stage of development of the Brazilian economy.[4, 5] As a function of the economic-technological specificity of the base industries, the generally observed patterns of energy use during this stage of industrialization point to a more energy-intensive production (the climbing of the so-called economic development "hill"[6]), leading to an overall increase in the average energy intensity (defined as the amount of energy consumed per constant 1985 US$ of output produced by the industrial sector).[7, 8] In the case of Industry in Brazil, the rising energy intensity was not caused by increasing energy intensities of particular industrial subsectors but by strutural effects alone. [9, 10] In fact, in the course of the past 20 years the general long-term trend for the average energy-intensity in Brazilian industry has been one of growth (Figure 1).

Figure 1 Evolution of Energy Intensity in Brazilian Industry, 1971-95 (1971=100)



Source: Our own elaboration, based on BRAZIL[11].
Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1 kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted).

Table 1 shows that the industrial sector's share of energy out of the country's total energy demand has gradually increased in conformity with the consolidation of the mature phase of the "Industrial Era."

Table 1 Evolution of the Relative Shares by Sectors of Final Energy Use in Brazil, 1971-95 (%)

	1971	1975	1980	1985	1990	1995
Industry	28.8	31.0	36.2	36.9	34.5	35.2
Residential	34.0	26.3	20.2	16.0	14.4	12.5
Transport	21.6	25.9	24.2	22.8	25.3	26.9
Other Sectors	15.6	16.8	19.4	25.8	25.6	25.3

Source: Our Own Elaboration, based on BRAZIL[11].
Note: Other Sectors = Agriculture + Commerce + Public Services + Non-Energy Use.
Counting hydro-electricity based on its calorific value (1 kWh = 860 kcal).

Notwithstanding this "natural" trajectory of the patterns of energy use for a national industry in the course of its structural consolidation as a mature Industrial Society, the mode of integration of the Brazilian Industry in the world economy during the 80s and 90s bears significantly on the shifts in the recent patterns of energy use in the country. The reason is that the export drive in recent years (exports grew from US$ 5.9 billion in 1971 to US$ 31.8 billion in 1994, based on 1985 prices) and, in particular, the kind of integration of the Brazilian industry had in the international market appear to have contributed to the increase of the energy-intensive character of the national industry.[12, 13]

Table 2 shows the evolution of the relative shares of selected groups in Brazilian exports during the 1971-94 period. The evolution of the shares by Groups of the total Brazilian exports in the last decades appears to leave no room for doubt that Brazil has progressively secured a place in the international market as a provider of energy-intensive industrial goods. Such a mode of integration appears to be related to three basic factors. The first is the stage of development that the Brazilian economy is undergoing, the so-called Industrial Era, characterized by the technical-economic paradigm that implies in energy- and materials-intensive production. The second is the ample supply of natural resources which allows the country to develop a comparative advantage in its basic materials processing industries of the Manufacturing Sector. And the last is referent to the assumed development strategy, based on the consolidation of Industry and which, during the 80s, became strictly a strategy for external adjustment, prompting the Government to "stimulate" further the export of an ever-growing share of the industrial production with a secure hold on the international market (policies going as far as to induce recessive processes domestically to generate export "surpluses").[14]

Table 2 Evolution of the Relative Shares by Sector of the Total Brazilian Exports and by Groups of the Brazilian Industrialized Exports Goods (in Value), 1971-94 (%)

	1971	1975	1980	1985	1990	1994
Total	100.0	100.0	100.0	100.0	100.0	100.0
Primary goods	75.1	58.0	42.2	33.3	27.8	25.4
Industrialized goods	23.6	39.6	56.5	65.6	70.4	73.2
Energy-intensive	6.9	10.8	20.6	28.7	36.0	35.8
Metallurgy	N.A.	4.3	6.0	9.5	14.8	18.7
Iron and steel	4.3	3.9	7.0	11.5	12.7	12.9
Steel-alloys	N.A.	1.4	1.6	1.3	1.7	1.2
Non-ferrous metals	N.A.	0.6	0.9	1.9	5.3	4.7
Chemicals	1.2	2.5	5.2	9.6	9.6	10.3
Pulp and paper	N.A.	1.7	4.9	3.6	5.8	5.9
Non-metallic minerals	1.4	0.6	1.0	0.8	0.9	0.8
Other Sectors	93.1	89.2	79.4	71.3	64.0	64.2
Food and beverages	32.5	29.2	27.7	19.6	15.6	13.4
Wood and furniture	15.9	3.3	3.4	1.8	1.8	3.0
Textile and leather	2.5	14.4	9.3	10.0	9.0	9.8
Machinery and transport equipment	12.4	26.6	30.1	23.2	26.1	29.0
Others	29.8	15.6	8.9	16.6	11.5	9.0

Source: Our Own Elaboration, based on BACEN[13].
Note: N.A. = Not Available. Primary goods = Agriculture + Mining and Pelletization.
Exports based on US$ in 1985 constant prices (exchange rate converted).
Individual entries for the Energy-Intensive Groups and for Other Sectors correspond to their respective shares over the total export of industrialized products in value. The summation of the data on exports of Primary and Industrialized Goods does not, however, total 100%. This difference is comprised of the share of the Special Transactions Group, which includes different items such as consumption of a ship's crew, for exemple.

The crux of the matter is that the worsening of the Brazilian external balance of payments in the 80s forced the country into a process of redirecting ever-growing portions of the domestic industrial production towards the international market (see Table 3). Of special note in this process is Metallurgy, Non-metallic Minerals, Pulp and Paper, and Chemicals sectors, all of which register significant increases in the export/production ratio in the order of 6, 4, 5 and 7 times, respectively, for the period 1975-94. By oversizing the energy-intensive industrial sectors, the current mode of integration of the Brazilian economy into the global market is a decisive contribution to the notable hypertrophying of the energy profile of the national industry, making more steep the economic development "hill" in Brazil.

This study is focused on the role of the integration of the Brazilian economy as a determining factor for the energy efficiency of the national industry. The work has been subdivided into three parts. The first part examines the volumes of energy embodied in Brazilian exported goods for the period 1971-1994, by contrasting the evolution in energy use by the country's Industry as a whole during the same period. In this manner, an overview of the process of intensification of energy use, observed with respect to the exported industrial goods, can be provided, as well as an evaluation of the consequent impact on the growth in industry wide average energy intensity in Brazil. The second part is comprised of simulations of nine scenarios for the Brazilian economy for the period 1995-2015, and is aimed at analyzing the sensitivity of the patterns of energy use in Industry with respect to the different modes of the country's integration in the global economy. The concluding section sketches out some considerations on the basis of the results of the simulations performed.

Table 3 Evolution of the Relative Shares of Industrial Exports in the Total Industrial Value Added and for Selected Industrial Sectors, 1975-94 (%)

	1975	1980	1985	1990	1994
Industry	8.6	14.2	17.3	18.7	21.6
Food and beverages	26.9	43.4	32.8	26.6	25.9
Textile and leather	11.8	13.3	17.7	19.3	28.9
Metallurgy	5.6	13.7	25.6	37.5	38.1
Non-metallic minerals	1.1	3.0	3.1	3.7	4.3
Pulp and paper	6.9	26.9	19.4	30.4	33.2
Chemicals	2.6	8.3	15.2	18.6	21.8
Others	6.8	10.9	13.9	13.8	16.8

Sources: Our own elaboration, based on BRAZIL[11] and BACEN[13].
Note: Industrial exports and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted). Mining and Pelletization are not included in the data for Industry.

PATTERNS OF ENERGY USE IN INDUSTRY RESULTING FROM THE MODE OF INTEGRATION OF THE COUNTRY IN THE GLOBAL ECONOMY

International exchanges can be analyzed through the in- and out-flows of materials and energy embodied in them.[15, 16, 17] Thus, in order to obtain a rough overall evaluation of the impact of the integration of Brazilian Industry in the international market, the amount of energy directly embodied in Brazilian exports by Sector and Industrial Group has been estimated. The methodology applied to this end consists in estimating the volumes of energy embodied in exported goods through the use of direct energy intensity coefficients for the different sectors (total final energy use of a sector over its Value Added). Table 4 shows the direct energy coefficients used in the estimates.

Table 4 Direct Energy Intensity Coefficients for the Brazilian Economy, 1971-94 (MJ/US$-85)

	1971	1975	1980	1985	1990	1994
Agriculture Sector	15.7	10.4	8.8	7.8	7.4	7.1
Industry Sector	17.1	15.4	15.9	19.5	19.5	20.6
Minig and pelletization	13.5	18.7	23.9	17.4	16.4	17.2
Food and beverages	54.8	39.3	37.5	39.0	33.5	41.3
Non-metallic minerals	56.6	61.1	46.8	49.6	46.9	45.6
Metallurgy	42.6	46.1	48.1	68.9	78.1	75.4
Chemicals	15.9	14.9	18.2	18.0	20.4	19.1
Pulp and paper	47.1	43.1	44.8	46.9	47.0	53.6
Textile and leather	7.7	5.9	5.1	5.2	6.8	7.0
Others	3.4	3.3	3.6	3.3	3.4	3.2
Energy Sector	25.9	27.3	32.4	41.4	38.3	37.7

Source: Our own elaboration, based on BRAZIL.[11]
Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1 kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted).

The amount of energy embodied in the exported industrial products has grown from about 33 PJ in 1971 to, roughly, 641 PJ in 1994 (see Table 5). Looking at the entire 1971-94 period, the energy embodied in the export of energy-intensive goods has grown about 14% per year. By 1975, the energy embodied in the Brazilian industrialized products for export exceeds the energy embodied in primary products (121 PJ as against 117 PJ). However, only since 1985, when the Government took the decisive steps to encourage and strengthen the export of products of the base industries,[3, 14] does the energy embodied in the products of the Energy-Intensive Group (243 PJ) exceed the energy embodied in the exported products of the Other Industrial Sectors (165 PJ).

Table 5 Evolution of the Energy Embodied in Brazilian Industrial Exports by Sector and by Selected Industrial Group, 1971-94 (PJ)

	1971	1975	1980	1985	1990	1994
Total	101.30	239.32	444.45	493.28	604.57	717.96
Primary goods	67.73	116.96	132.69	83.54	74.75	75.92
Industrialized goods	33.30	121.04	310.52	408.82	528.28	640.57
Energy-intensive	4.01	29.25	125.46	243.03	384.99	462.82
Metallurgy	N.A.	18.17	67.97	170.20	282.54	326.25
Iron and steel	2.50	11.92	50.16	133.00	182.50	224.87
Steel-alloys	N.A.	4.31	11.39	15.55	24.70	20.27
Non-ferrous metals	N.A.	1.94	6.42	21.65	75.33	81.10
Chemicals	0.43	4.03	17.75	38.42	44.62	54.67
Pulp and paper	N.A.	4.74	32.64	28.04	50.08	73.05
Non-metallic minerals	1.08	2.31	7.10	6.37	7.75	8.85
Other Sectors	29.29	91.79	185.05	165.79	143.29	177.75
Food and beverages	24.50	75.34	154.70	127.79	96.09	127.75
Wood and furniture	0.74	0.72	1.79	1.01	1.10	2.21
Textile and leather	0.27	5.60	7.09	8.68	11.14	15.90
Machinery and transport equipment	0.58	5.79	15.95	12.73	16.22	21.48
Others	3.21	4.33	5.53	15.59	18.75	10.42

Source: Our own elaboration, based on BRAZIL[11] and BACEN[13].
Note: N.A. = Not Available. Primary goods = Agriculture + Mining and Pelletization.
Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1 kWh = 860 kcal). The difference in the totals for Primary and Industrialized Products corresponds to the share of Special Transactions, which is part of BACEN's tallying.[13]

A significant portion of the energy used by Industry is being transferred abroad through the export of industrialized goods. Table 6 shows that, in 1971, the quantity of energy embodied in industrial goods for export represented no more than about 5% of the total energy used by the country's industry, but reaching 29% by 1994.

Table 6 Evolution of the Share of the Energy Embodied in Brazilian Industrial Exports Out of Industry's Total Final Energy Use, 1971-94 (%)

	1971	1975	1980	1985	1990	1994
Industry	4.0	10.6	18.9	21.6	27.4	28.9
Food and beverages	9.1	25.5	42.3	32.4	25.5	25.9
Non-metallic minerals	0.8	1.1	3.0	3.1	3.7	4.3
Metallurgy	1.3	5.7	13.7	25.6	37.5	38.1
Iron and Steel	1.5	4.5	12.8	25.9	33.3	36.6
Steel-alloys	N.A.	39.1	48.1	40.8	55.0	39.7
Non-ferrous metals	N.A.	4.4	7.8	18.7	47.0	42.5
Chemicals	0.7	4.4	10.4	20.3	23.0	26.3
Pulp and paper	N.A.	7.0	26.9	19.4	30.4	33.2
Textile and leather	0.7	12.1	13.3	17.7	19.6	28.9
Others	5.0	8.0	11.5	18.0	20.7	18.9

Sources: Our own elaboration, based on BRAZIL[11] and BACEN[13].
Note: N.A. = Not Available. Mining and Pelletization are not included in the data on Industry.
Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1 kWh = 860 kcal).

The share of the Energy-Intensive Group out of the total energy embodied in industrial exports as a whole increases from 12.0% in 1971 to 40.4% in 1980, and to above 70% in the 90s (see Table 7). The share of the economic output of Brazilian Industry transferred abroad comprises, on average, more energy-intensive products than their proportion in the total economic output of the national industry (the ratio of energy intensity of exports to industrial products as a whole is greater than 1 throughout the period).

Table 7 Evolution of the Energy Embodied in Industrial Exports on Total Energy Use in Industry and the Share of the Energy-Intensive Groups Out of the Energy Embodied in Industrial Exports, 1971-94

	1971	1975	1980	1985	1990	1994
$EEIX_{EIG}/EEIX$ (%)	12.0	24.2	40.4	59.4	72.9	72.3
e_x/e_t	1.41	1.19	1.30	1.25	1.47	1.34

Sources: Our own elaboration, based on BRAZIL[11] and BACEN[13].
Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal). EEIX = Energy Embodied in Industrial Exports, FEUI = Final Energy Use in Industry, $EEIX_{EIG}$ = Energy Embodied in Industrial Exports of Energy-Intensive Goods; and e_x/e_t = Energy Intensity of Industrial Exports / Energy Intensity of Industry Ratio.

The energy embodied in exported industrial goods has comprised a significant share of final energy use in the Brazilian Industry in the 80s and 90s. This is not only a reflection of the ever growing importance of industrial exports in relation to the total value of the economy's industrial output, but is also a consequence of the increased share of the Group of Energy-Intensive goods in the country's industrial exports (7% in 1971, 21% in 1980 and 36% in 1994). Thus, the mode of international market penetration of Brazilian industrial goods for export during the 80s and 90s is, to a great extent, responsible for making the Brazilian National Industry more energy-intensive overall. To overlook the importance of the mode of integration of Brazil's industrial production in the international market may prove a grave shortcoming for analyzing the evolution of industrial patterns of energy consumption in the past few decades in the country, and must be given its due weight in the elaboration of effective energy policies aimed at promoting energy efficiency in the near future.

TRENDS OF ENERGY USE IN THE BRAZILIAN INDUSTRY

Projections of the amount of energy embodied in industrial export goods and total industrial energy use are made in accordance with the simulations of specific scenarios for the evolution of the Brazilian economy for the 1995-2015 period. Three basic trajectories for external integration of Industry in the international market have been outlined, yielding: (1) a profile for exports that are less energy intensive (a reduction in the share of the Energy-Intensive Group, from now on Scenario I); (2) an unaltered profile of export items (the current share of the Energy-Intensive Group remaining constant, from now on Scenario II); and (3) a more energy-intensive profile for exports (an increased share of the Energy-Intensive Group, from now on Scenario III).

Methodology and assumptions

For simulation purposes, a suitable methodology for estimating the energy embodied in industrial exports and total energy use by Industry in Brazil has been elaborated.[14] The methodology is premised on the decomposition of energy-referent data into data at the level of industrial economic output (Industrial Value Added) and the average energy intensity of the economic product. In others words, energy use within each industrial subsector "i" (FEU_i) is equal to its economic output (IVA_i), in Value Added terms, times its energy intensity (e_i or $[FEU_i/IVA_i]$); i.e., $FEU_i = IVA_i \times e_i$ (index "i" represents each industrial subsector). In this sense, it is easy to demonstrate that the average energy intensity (e_t) is itself the result of the interaction of the composition of the economic output - the shares of the various industries in the total economic product or Industrial Value Added (IVA_t); i.e., S_i or IVA_i/IVA_t - with the different energy intensities according to type of industry (e_i); i.e., $e_t = \Sigma S_i \times e_i$ (index "t" means total, or the sum of all industrial activities). So, Industry's overall energy use ($FEUI_t = \Sigma FEU_i$) is equal to IVA_t (i.e, ΣIVA_i) times e_t (i.e., $FEUI_t = \Sigma S_i \times e_i$).

To enphasize the impact of energy embodied in industrial exports on industrial energy use IVA is decomposed into two componentes: foreign market oriented activities, i.e. industrial exports (IX_t), and domestic market oriented activities (IVA_t-IX_t). Similarly, Industry's overall energy intensity (e_t) is decomposed into energy intensity of industrial exports (e_x) and energy intensity of domestic market oriented industry (e_d), weighted by the share of industrial exports in IVA (IX_t/IVA_t) and the share of domestic market oriented industry in IVA ($[IVA_t-IX_t]/IVA_t$), respectively ($e_t = [e_x \times (IX_t/IVA_t)] + [e_d \times ([IVA_t-IX_t]/IVA_t)]$). The energy intensity of industrial exports as a whole (e_x) is thefore subdivided in the energy intensity of each subsector "i" of the industrial exports (e_i) and its respective weight in total industrial exports (IX_i/IX_t). The energy intensity of each subsector "i" of industrial exports is assumed to be equal the energy intensity of the subsector "i" itself (see Table 4), so that the differences between the average energy intensity of industrial exports and the average energy intensity of domestic market oriented industry are due to diferences in the economic product compositions alone.

The dynamic variable (the independent variable) of the model is the Industrial Value Added (IVA), and the various weights (IX_t/IVA_t, $[IVA_t-IX_t]/IVA_t$, and IX_i/IX_t) and energy intensities (e_d and e_x) are the parametric variables.Therefore, by assuming different growth rates for the Industrial Value Added (IVA), different shares for energy-intensive goods on total exports, and different energy intensities (e_d and e_i), it is possible to estimate the energy embodied in Industrial Exports and the energy use in Industry. In this way it is possible to understand how the evolution of energy embodied in industrial exports can impact the evolution of total industrial energy use.

The delimitation of the simulations involves defining the hypotheses for the behavior of the independent variable (IVA) and of the parameters of the model on the basis of the available information from other studies.[18, 19, 20] The base case is defined as one where the Brazilian economy will come to assume a profile of greater international integration during the period 1995-2015, with moderate rates of growth of the industrial economic output.

In all situations examined the Industrial Value Added (IVA) is assumed to increase: 3.5% per year during the 1995-2005 period, and of 5.5% per year during the subsequent period (2005-2015). In all situations Industry assumes a more export-oriented profile, thus enlarging further the share of industrial exports out of the Industrial Value Added from 21% in 1995 to 30% from 2010 onwards (25% in 2000, and 28% in 2005). This evolution appears to be compatible with the process of market liberalization that the Brazilian economy is undergoing (the average rate of growth of XI/IVA of the first half of the 90s being maintained up to 2000), and with the likely perspective of an imminent integrated global economy.[19]

Concerning the mode of integration of the Brazilian economy in world economy, three basic scenarios have been elaborated: one of reduction of the share of the Energy-Intensive Group on industrial exports (from 36% in 1995 to 30% in 2005, and maintaining this level up to 2015); another where the share of the Energy-Intensive Group on industrial exports is maintained constant (36%); and finally one where the share of the Energy-Intensive Groups over industrial exports increases (from 36% in 1995 to 40% in 2000, maintaining this level until 2015).

Additional hypotheses on the evolution of industrial energy intensity have been elaborated: (1) 2% reduction per year; (2) 1% reduction per year; and (3) no variation. It is important to bear in mind that these hypotheses for evolution of the Brazilian industry are applied to both the energy intensity of domestic market oriented industry as a whole and the energy intensity of each subsector "i" of the industrial exports (index "i" represents different industrial subsectors, like Metallurgy, Pulp and Paper, Chemicals, etc.).

Can the profile of Brazilian exports determine the future energy efficiency of its industry?
Tables 8 presents the estimates for energy embodied in industrial exports (EEIX) and Figures 2, 3, 4 and 5 present the share of the energy embodied in industrial exports on Industry's final energy use (from now on EEIX/FEUI) and the average energy intensities of industrial exports (e_x) and overall Industry (e_t) according to each Hypothesis, respectively. Notice that a new scenario (Scenario 0), a business-as-usual scenario, which serves to explore the relevant parameters for the case of 1995 (level of liberalization of the economy, energy intensity and share of energy-intensive goods on industrial exports) is included, varying only the rate of growth of the Industrial Value Added (following the same rate used in the other 9 situations).

In terms of the energy embodied in industrial exports, Table 8 shows that, for each of the three Hypotheses of gains in energy efficiency considered (2%, 1% and 0%/yr), the range of variantion in the results for the year 2015, as a function of the mode of external integration of the Brazilian Industry that year (share of energy-intensive exports on total industrial exports varying from 30% to 40%, down or up from 36% in 1995, respectively) is always in the order of 18%.

When the volumes of energy embodied in industrial exports are contrasted with the total final energy use in Industry (see Figure 2), results reveal that, by virtue of the ongoing economic liberalization in the country, the relation EEIX/FEUI increases in all three Scenarios under consideration, from about 28% in 1995, to 37% in Scenario I, to 39% in Scenario II and to 40% in Scenario III in 2015. That is, the range of variation of the results obtained for the year 2015 in terms of industry's total final energy use as a function of the mode of

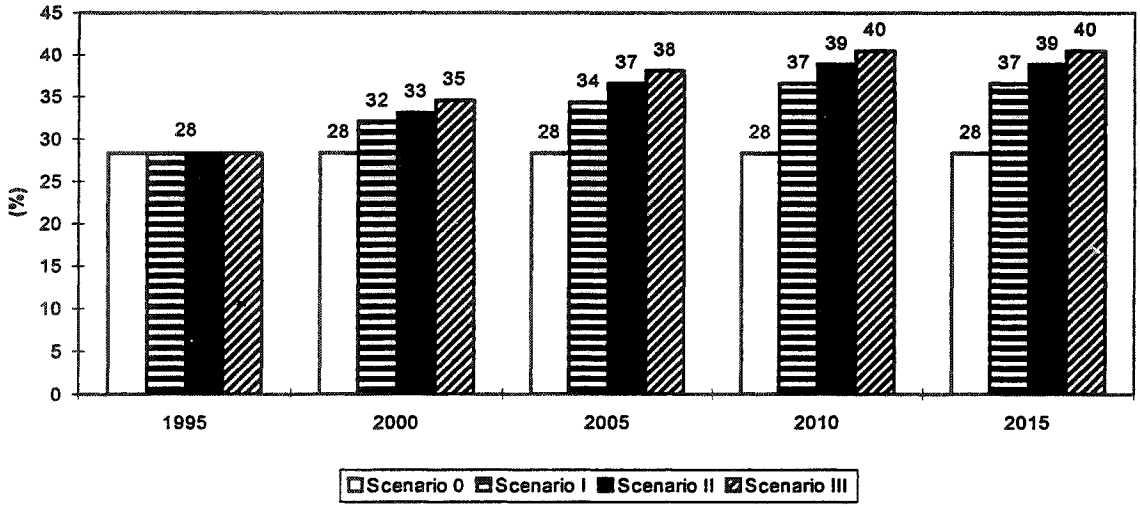
integration in the international market is in the order of 6.5%. In terms of fractions of IVA, the energy embodied in industrial exports increases from 21% in 1995 to 30% from 2010 onwards. In other words, in Scenario III the share of the energy embodied in industrial exports on total industrial energy use is kept constant over time, meaning that energy efficiency gains are not enough to offset the other factors involved.

Table 8 Evolution of Energy Embodied in Industrial Exports and of Total Energy Use in Industry according to the Different Scenarios and Hypotheses (PJ)

	1995		2000		2005		2010		2015	
Scenario 0	679	(2,396)	806	(2,845)	958	(3,379)	1,252	(4,417)	1,636	(5,772)
Hypothesis I										
Scenario I	679	(2,396)	827	(2,577)	944	(2,747)	1,196	(3,266)	1,413	(3,858)
Scenario II	679	(2,396)	866	(2,616)	1,041	(2,844)	1,319	(3,388)	1,558	(4,003)
Scenario III	679	(2,396)	924	(2,674)	1,111	(2,914)	1,408	(3,477)	1,663	(4,108)
Hypothesis II										
Scenario I	679	(2,396)	870	(2,711)	1,045	(3,041)	1,393	(3,803)	1,731	(4,726)
Scenario II	679	(2,396)	911	(2,752)	1,153	(3,148)	1,536	(3,946)	1,909	(4,904)
Scenario III	679	(2,396)	972	(2,813)	1,230	(3,226)	1,639	(4,049)	2,037	(5,033)
Hypothesis III										
Scenario I	679	(2,396)	915	(2,851)	1,156	(3,362)	1,619	(4,421)	2,116	(5,779)
Scenario II	679	(2,396)	958	(2,894)	1,274	(3,481)	1,785	(4,588)	2,333	(5,996)
Scenario III	679	(2,396)	1,022	(2,958)	1,360	(3,567)	1,906	(4,708)	2,491	(6,153)

Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal). Total Energy Use in Industry within brackets. Hypotheses I, II and III: 2%, 1% and 0%/yr reduction in the energy intensity of each industrial subsector over time, respectively. Scenarios I, II and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30%, is kept constant at 36% or increases to 40% in year 2015, respectively.

Figure 2 Evolution of the Share of the Energy Embodied in Industrial Exports on Total Energy Use in Industry (%)

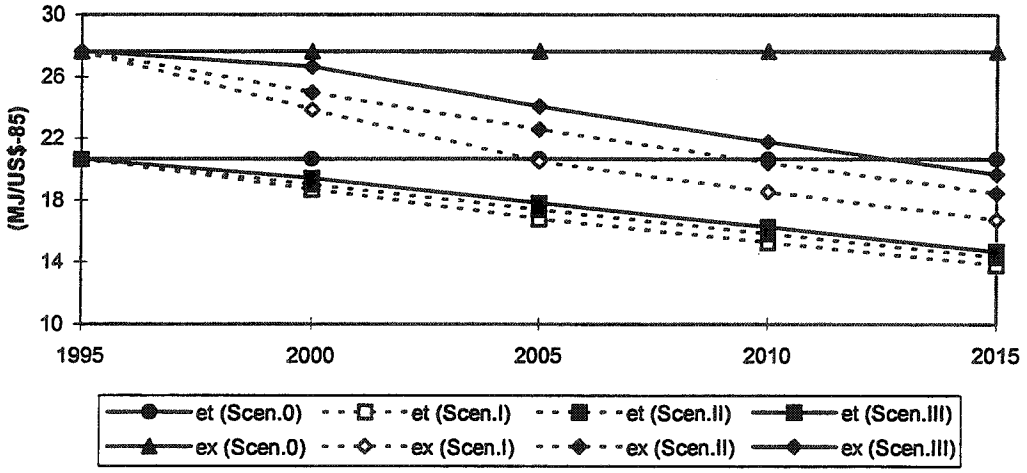


Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal). Scenarios I, II and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30%, is kept constant at 36% or increases to 40% in year 2015, respectively.

It is important to note that the values of the relation EEIX/FEUI for a particular Scenario and for the specific years, under the different Hypotheses, however, do not change (Scenario I for each of the three Hypotheses, and thus successively). This can be explained as the result of keeping the proportionality of the assumptions made. Thus, only the absolute numbers are modified, with the ratio between EEIX and FEUI remaining unaltered in specific years regarding different Hypotheses.

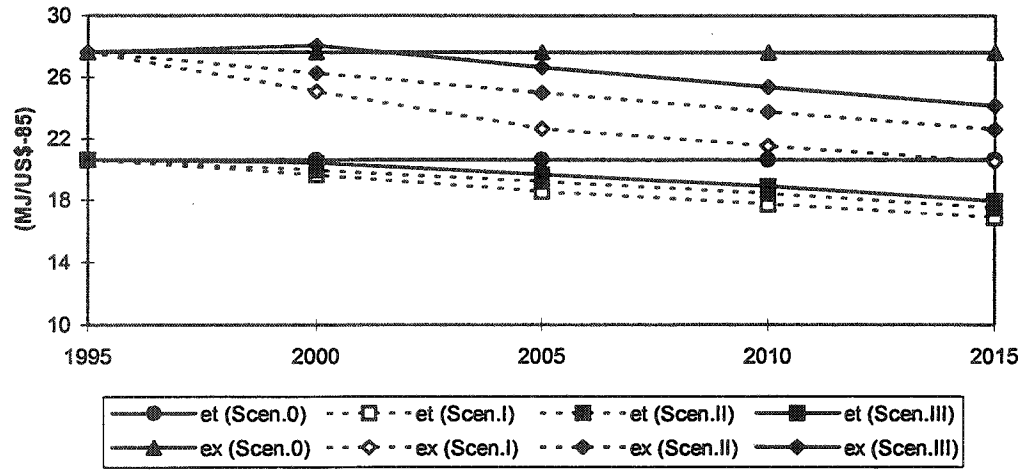
Figures 3, 4 and 5 present the evolution of the average energy intensities of the Brazilian industrial exports (e_x) and of the overall Industry (e_t) according to the different Scenarios for each Hypothesis, respectively. In terms of e_x, regarding Hypotheses I and II (Figures 3 and 4, respectively), all three Scenarios show trends of decline of the average energy intensity of the Brazilian industrial exports during the 1995-2015 period.

Figures 3 Evolution of the Average Energy Intensities of Industrial Exports and Overall Industry: Hypothesis I (MJ/US$-85)



Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted). Hypothesis I: 2%/yr reduction in the energy intensity of each industrial subsector over time. Scenarios I, II and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30%, is kept constant at 36% or increases to 40% in year 2015, respectively. e_x = energy-intensity of industrial exports and e_t = energy-intensity of overall Industry.

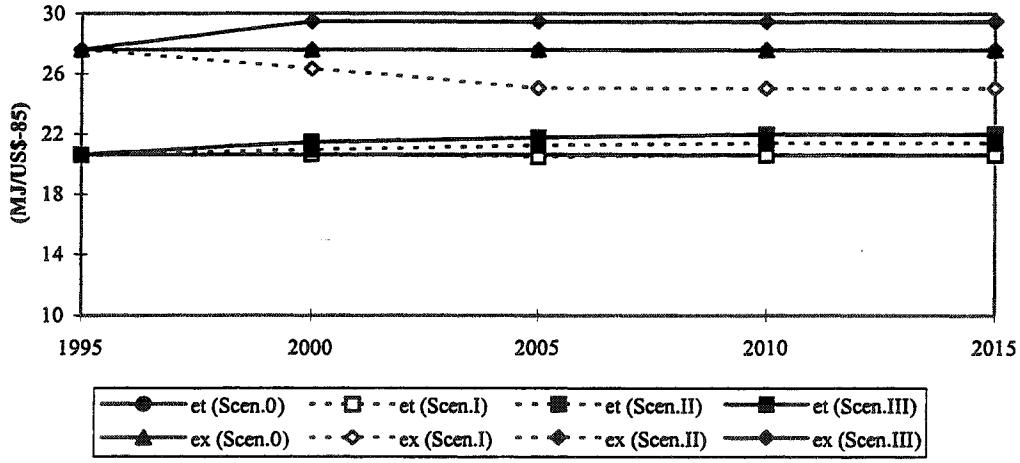
Figures 4 Evolution of the Average Energy Intensities of Industrial Exports and Overall Industry: Hypothesis II (MJ/US$-85)



Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted). Hypothesis II: 1%/yr reduction in the energy intensity of each industrial subsector over time. Scenarios I, II and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30%, is kept constant at 36% or increases to 40% in year 2015, respectively. e_x = energy-intensity of industrial exports and e_t = energy-intensity of overall Industry.

Figure 5, according to Hypothesis III (no gains in energy efficiency over time), trends in e_x will depend on the scenario considered.

Figures 5 Evolution of the Average Energy Intensities of Industrial Exports and Overall Industry: Hypothesis III (MJ/US$-85)



Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted). Hypothesis III: 0%/yr reduction in the energy intensity of each industrial subsector over time. Scenarios I, II and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30%, is kept constant at 36% or increases to 40% in year 2015, respectively. e_x = energy-intensity of industrial exports and e_t = energy-intensity of overall Industry.

The effects of energy efficiency gains on the average energy intensity of industrial exports may be large or small, or even null (when gains are modest, between 0% and 0.5%/yr, for example), depending on the mode of integration of the Brazilian Industry in the international market.

Figures 3, 4 and 5 also highlight the effects of the energy intensity of industrial exports on the overall energy intensity of Industry. It can be observed that, for the 1995-2015 period, the average energy intensity of Industry, under Hypothesis I, decreases, on average, 1.74%/yr in Scenario I, as opposed to the average decrease of 1.46%/yr in Scenario III. With respect to Hypothesis II, the average rates of decrease for Scenarios I and III are 0.87% and 0.60%/yr, respectively. Under Hypothesis III, positive variations in the average energy intensity are registered throughout the period. For Scenario I, the annual average rate increase is practically null, keeping the average energy intensity of Industry as a whole pretty stable (since the latter is compensated, to a great extent, by the smaller share of the energy-intensive goods out of the total industrial exports). In Scenario III, however, this rate increases 0.28%/yr.

As can be ascertained, the ratio e_x/e_t presently around 1.34 (that is to say, industrial exports beeing, roughly, 34% more energy- intensive than the average IVA) decreases further to 1.21 and 1.29 in Scenarios I and II, respectively, in 2015; while in Scenario III this ratio remains 1.34 in that same year. Again, as in the case of the relation EEIX/FEUI mentioned above, the values of the ratio e_x/e_t, for a particular Scenario and for specific years, under the different Hypotheses, do not change due to the proportionality of the assumptions made.

In conclusion, we confirm that structural changes in Brazilian exports alone may come to offset efficiency improvements made in the country's Industry as a whole if energy efficiency gains over time are kept relatively modest (less than 1%/yr).

FINAL CONSIDERATIONS

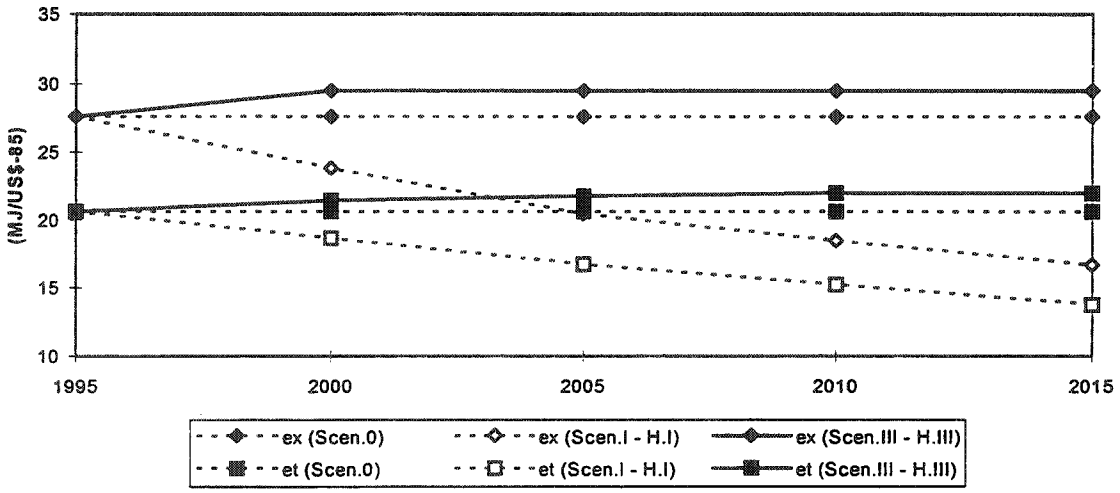
Recent studies have estimated an energy conservation potential in the industrial sector of developed economies ranging from 11 to 37%. [20, 21, 22, 23] Although technically attainable for Brazilian Industry as well, [10] the results of the simulations performed in this study indicate that efforts to reduce energy intensity on the part of Brazilian

Industry as a whole and with respect to industrial export goods in particular may be boosted (Scenario I) or hampered (Scenario III), depending on the specific mode of international integration of the country's Industry.

We have shown (Table 8) that an effective energy conservation policy aimed at moderate energy savings (Hypothesis I) may lead, in Scenario I (a smaller share for the energy-intensive goods on total industrial exports), to a reduction in final energy use in Industry, in 2015, in the order of 33.2% as compared to Scenario 0 (*business-as-usual*). In Scenario III (a greater share for the energy-intensive goods), the reduction would be of 28.8% in 2015; that is, roughly 4.5 percentage points lower. In the case of an energy conservation policy aimed at promoting only modest energy efficiency improvements (Hypothesis II), these percentage will be even smaller: 18.1%, in Scenario I, and 12.8%, in Scenario III both in reference to Scenario 0. Finally, if no energy efficiency efforts are made (Hypothesis III), total industrial final energy use will increase as compared to Scenario 0. This can be explained as a consequence of the increased share of industrial exports (which are, on the average, more energy-intensive) over the Industrial Value Added in Scenarios I, II and III. Thus, final energy use in 2015, Scenario I, will be the same as in Scenario 0; while in Scenario III final energy use will be 6.6% greater than in Scenario 0.

Figure 6 depicts the range of the results in terms of e_x and e_t according to the different Scenarios. It shows that e_x and e_t would present downward or upward trends, depending upon the Hypotheses of energy efficiency gains and on the specific mode of international integration of the country's Industry. A larger share of the energy-intensive group in industrial exports would demand a greater effort in terms of energy efficiency improvements to offset its effects on the energy intensity of Industry as a whole. Simulations assuming modest energy efficiency gains per year (0.5%) show that a more energy intensive mode of integration of the Brazilian economy in the world economy can offset the downward effect over the energy intensity of Industry as a whole.

Figure 6 Range of the Results in Terms of the Energy Intensities of Industrial Exports and of Overall Industry (MJ/US$-85)



Note: Energy figures are in terms of final energy. Counting hydro-electricity based on its calorific value (1kWh = 860 kcal) and Industrial Value Added based on US$ in 1985 constant prices (exchange rate converted). Hypotheses I and III: 2% and 0%/yr reduction in the energy intensity of each industrial subsector over time, respectively. Scenarios I and III: share of energy-intensive exports on total industrial exports from 36% in 1995 to 30% or increases to 40% in year 2015, respectively. e_x = energy-intensity of industrial exports and e_t = energy-intensity of overall Industry.

It can, thus, be concluded that the smaller the gains in energy efficiency in the various industrial sectors, the greater will be the influence of the mode of external integration of the Brazilian economy on the patterns of energy use in Country's Industry as a whole as well as on its average level of energy efficiency. The lesson that can be derived on the basis of the results of this work is that a more energy-intensive mode of international integration for Brazilian industrial exports may endanger the effectiveness of measures aimed at promoting the more efficient use of energy in the Brazilian Industry in the future.

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