SPECIAL REPORT

The energy crises and metals consumption and production in LDCs

By André T. Furtado and Saul B. Suslick

This paper presents a historical analysis of the evolution of the energy and metals consumption and production in less developed countries (LDCs), encompassing a period of 25 years (1965 – 90), focusing specially on Latin America and on Brazil. The period permits an evaluation of the impact of the energy crisis on patterns of economic growth, associated to energy and metal production profiles in developing and developed countries. This complex relationship is evaluated, using aluminium, copper and crude steel consumption and production profiles.

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The growth in metals and energy consumption has often been considered as a threat to the world economic development. However, since the energy crisis of 1973, an atrophy of this growth rate has been observed. Given the increase in the price of energy, many countries took important measures to reduce energy consumption. The same atrophy was observed in the case of consumption of some metals. These trends differed between countries groups. Developed countries (DCs) seem to have gone through deep transformation of their energy consumption patterns. They have changed from an energy-intensive path, before the energy crisis, to a more energy-saving path afterwards. Meanwhile, several authors and international institutions are concerned by the fact that many less developed countries (LDCs) reveal levels of energy consumption above the world average. Most of those countries, including Brazil, currently faces a growing need for energy services to support economic and social development (Goldemberg et al. 1987; Levine and Meyers, 1992). Such an evolution can thus generate serious problems to LDCs economic development.

The reasons for the different growth rates of energy consumption between the LDCs and DCs are difficult to assess.[1] Institutions such as the GEF Global Environment Facility, supported by World Bank and United Nations, insists on the necessity to diffuse technologies and energy systems that are environmentally efficient. Although the diffusion of such technologies is important to adjust the energy-intensive paths of LDCs, there is a need to examine more deeply the key variables determining the evolution of energy consumption profile in LDCs.

To what extent these trends are also present in metal consumption and production of LDCs? Latin America (including Brazil) has emerged in recent years as a significant source of demand for metals. Nappi (1989), Radetzki (1990), and Tilton (1990) showed that after 1974, the consumption of most unwrought metals in DCs declined or remained stable. Why do the metal consumption patterns differ between these countries groups?

Finally, besides an increase in metal demand, an expressive expansion of metal production due to exported-oriented or import-substitution policies may be observed in LDCs. Metal production, much more than demand, may provoke an increase in energy demand in these countries. Strout (1985) has analysed the impact of metal production on energy consumption. The author estimated that the production of 17 non-fuel commodities was responsible for approximately of 27 per cent of the world primary energy consumption. Aluminum, copper, and steel that will be used in this study are responsible for 20 per cent of world totals. As for demand, Brazil and Latin American countries follow much more intensively this pattern.

Methodology Proposed

In order to shed some light on these problems and issues, this paper analyses the evolution of energy and metals consumption and production patterns for the world as whole and for different groups of countries. Metal production is introduced in our analysis because of its links with energy consumption. Moreover, metal production showed a greater propensity to increase in LDCs than metal consumption. Thus, metal production could indicate, more than its consumption, that important changes are taking place in the economic structure, especially for those countries which are metal exporters.

The analysis covers the years 1965 – 90 which may be divided into three different periods:

- Period 1 (1965 – 73): Petroprosperity (Puisseux, 1979);
- Period 2 (1973 – 85): Energy Crisis and Structural Changes;
- Period 3: (1985 – 90): Relative Recovery.

These three periods are associated with important discontinuities in the world economic activity. The description of these three periods will be based upon the analysis of the GDP, the intensity of energy-IE (the ratio between the energy consumption, CE, and GDP), the intensity of use (IU – the metals consumption to GDP ratio). An intensity of production ratio (IP) is also introduced to better explain the structural changes that occurred since the first oil shock. This coefficient may be defined as the ratio of the quantity of mineral commodity produced by a country (Pt) in year t to its gross domestic product (GDPt). The main objective is to show that metal production presented a more diverse evolution than metal consumption between LDCs (including Brazil) and DC's after the first oil-shock.

Energy crisis and structural changes in material demand

The energy crisis of 1973 provoked an important discontinuity in long term trends of consumption for both energy and metals (IEA, 1981; Goldemberg et al. 1987; Tilton, 1986; Roberts, 1987). Thus, there was a rupture at world level between income evolution and energy and metal consumption. Even if the former was still increasing (although at a slower pace), the latter stabilized or even dropped for some metals.

The traditional explanation for the atrophy in metals and energy consumption relatively to income has been popularized by Malenbaum, which maintains that the intensity of use is closely linked to the level of per capita income or to a country's level of economic development. This hypothesis has also been verified in the case of energy for industrialized countries (Schurr, 1984). The bell shape of IU or IE related to time or to per capita income seems to be almost an universal phenomena associated with industrialization and the change of demand patterns (this is why Hwang and Tilton, 1990, refer to it as "consumer preference school"). In the first stage of industrialization an increase in the consumption of goods stimulates the use of metals and of energy. However, as the industrialization process grows, and as some important needs are satisfied, such as housing, transportation, infrastructure, and equipment, and other urban facilities, development starts to change qualitatively. Technological change increases efficiency in materials use while higher income stimulate the consumption of less material intensive goods and service.

A second school of thought (the "leapfrogging school") (Hwang and Tilton, 1990) emphasizes the effects of technological progress over time. It suggests that latecoming industrializing countries may take advantage from more efficient technologies for their takeoff period, when material intensity of use rises quickly, and follow less material intensive patterns than those adopted in the past by the actual industrialized countries for a same level of economic development. A variation on the same theme has been suggested by Waddell & Labys (1988) and Bernardini & Galli (1993): the dematerialisation approach. In this latter case, technical progress is internalized like a secular phenomena which progressively reduce energy and metals for the same level of output and the same stage of development.

Even if the leapfrogging school considers a tendency for material intensity of use to drop over time, it is of little help to understand great discontinuities in patterns of demand caused by stochastic phenomenon such as the energy crisis. To understand discontinuities, must be given a closer look in the theories of technical change. Freeman and Perez (1988) suggests that modern history is strongly influenced by the emergence of innovations clusters that are at the base of new phases of economic prosperity (Freeman and Perez, 1988). Hence, some technological change may have strong and deep effects on all the sectors of the economy for a long period of time. The new cluster of innovation is followed by a new best practice set of rules and customs for designers, engineers, entrepreneurs and managers, determining what may be called a new "technico-economic paradigm". New and old sectors are transformed by these technologies and the new set of rules and customs. As a new paradigm emerges, profound discontinuities may be observed. This school of thought suggests that a new technico-economic paradigm (intensive in information and communication) is emerging since the beginning of the 1970s. This new paradigm may explain the radical changes observed in the patterns of materials consumption during the postwar period. The new dynamic sectors in the industry, almost all linked to information technologies, consume energy and metals much less intensively. The service sector also increased more rapidly than primary and manufacturing sectors, given the growing importance of communications. Hence, the emergence of the new technico-economic paradigm has implied a shift from an energy-intensive pattern of growth to a less intensive one.

It may, thus be hypothesized that the energy crisis caused the emergence of a new information intensive techno-economic-paradigm, which provoked a discontinuity with past trends in material consumption. As a consequence, DC's economies reshaped dramatically their energy and metal consumption profiles.

According to Goldemberg et al .(1987), these economies have entered the post-industrial phase of economic growth, in which service sector grows rapidly relative to the good-producing sector while the manufacture of goods shifts to products characterized by a high ratio of value added to material content.

Meanwhile, the reaction of LDCs to the energy crisis seems more difficult to categorize. Aggregate studies recognize that IU continued to grow after the first petroleum shock of 1973 (Radeztki 1990). The same may be observed for energy since their IE continue to grow after this period. The "consumer preference school" would explain this result by the fact that younger economies were just moving on the ascending part of their IU and IE long term curves.

However, such an interpretation disregards the fact that LDCs per capita income rate of growth decelerated during the mid-1970s. Some were more affected than others, but on balance, the net effect was a declining one.

Although LDCs have suffered heavily from the negative impacts of the energy crisis, they have almost not been affected by the structural changes that modified the economic structure of DCs. The literature about metal consumption suggests that some newly industrializing countries have been accelerating their use of metals (Radetzki, 1990; Hwang and Tilton, 1990). This increase was partly due to the export shift, which occurred during the 1980s, to manufactured goods that use metals more intensively (cars and ships for example). Other countries in Africa and Latin America suffered more deeply from the energy crisis and showed declining values for their IU ratios. However, in the case of Latin America, this decline was followed by an increase of their metals exports and of their energy intensity (Suslick & Harris, 1991).

This paper tries to demonstrate that the metals and energy consumption profiles may be closely linked to one another, that discontinuities may appear and that groups of countries may let different trends appear. The "consumer preference" and the "leapfrogging" schools of thought suppose continuous trends as the country moves to an higher stage of economic development or as it accumulates more technical knowledge. However, technical change cannot always be considered as a continuous phenomenon. The diffusion of a cluster of radical innovations may improve dramatically the investment opportunities and modify the technical constraints of a given economy.

Important discontinuities have affected the world economy during the last decades. The energy crisis of the 1970's (a stochastic phenomenon) induced a shift to a new information-intensive paradigm. This has modified the metals and energy consumption profiles. But this may not be an universal phenomena affecting simultaneously all the countries. The rate of diffusion of the new techno-economic paradigm may vary considerably between groups of countries. The leapfrogging approach seems to consider that this rate of diffusion is much more rapid in young economies than in the older ones, which implies that the IE and IU should be declining faster in LDCs than in DC's. However, suggested by this paper, the intensity ratios of LDCs do not seem to follow a downward trend at all.[2]

Table 1. GDP, Primary energy consumption (CE) and intensity of energy (IE) for regions. Average (per cent) annual rate of change, 1965 – 90

	Average Annual Growth Rates				
	Brazil	LA	LDC	DC	World
GDP					
1965 – 73	9.81	6.48	6.60	4.81	5.09
1973 – 80	6.73	5.32	5.27	2.71	3.19
1980 – 85	2.56	1.26	1.64	2.07	2.16
1985 – 90	2.12	1.52	3.70	3.16	3.47
Energy Consumption (CE)					
1965 – 73	11.53	6.56	7.21	4.89	5.24
1973 – 80	8.07	5.29	5.97	1.22	2.76
1980 – 85	2.94	2.93	4.41	-0.57	0.94
1985 – 90	2.36	3.64	5.34	1.75	2.24
Energy Intensity (IE)					
1965 – 73	1.58	0.09	0.59	0.08	0.14
1973 – 80	1.30	-0.02	0.68	-1.46	-0.42
1980 – 85	0.56	1.69	2.73	-2.60	-1.20
1985 – 90	0.30	2.12	1.63	-1.37	-1.20

Source: Energy - BP Statistical Review (1991) and Balanço Energético Nacional (1976,87,91); GDP - World Bank, IMF e IBGE.
Notes: CE: energy consumption; IE: intensity of energy; GDP-Gross Domestic Product; LA: Latin America; LDC: Less Developed Countries; DC: Developed Countries.(*) Primary Energy includes only commercial forms

Petroprosperity (1965 – 73) and metals

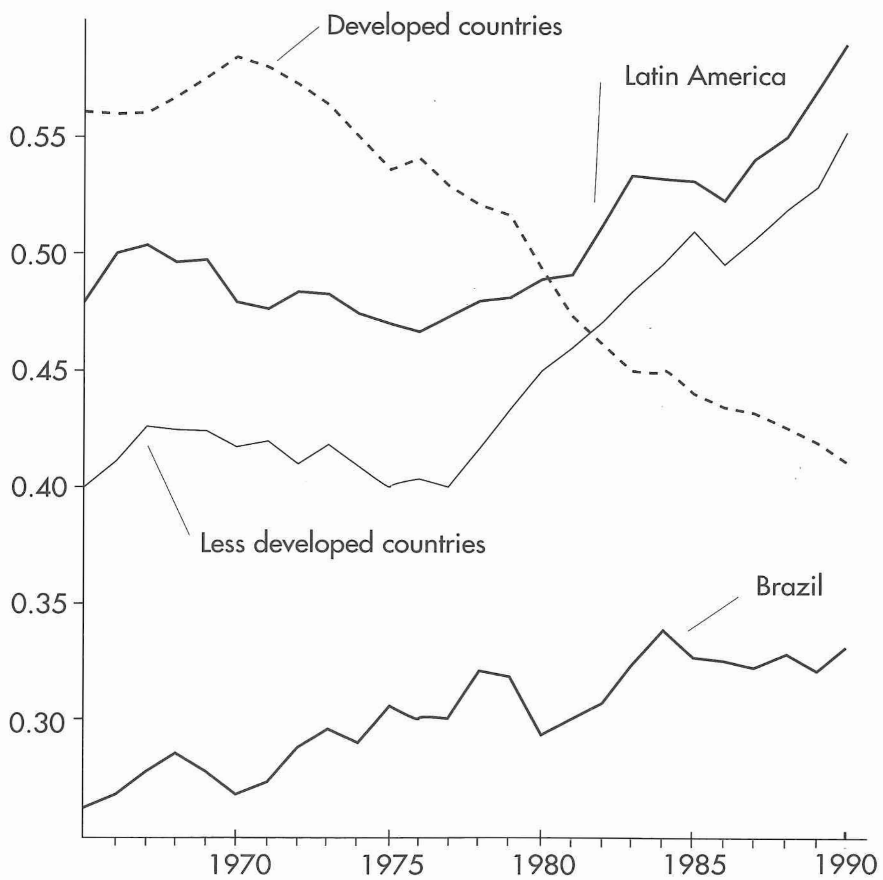
The postwar period was characterized by a fast economic growth based upon the oversupply of petroleum resources at low prices. The average growth rate of world economy was surpassed the 5 per cent level during that period (Table 1). DC's economies grew at rate quite similar to the world average, while LDCs gross domestic product growth rate was much higher (6.6 per cent). Brazil experienced during that period a GDP growth rate of almost 10 per cent quite above the LDCs average. This result reflects fast industrialization process which characterized the Brazilian economy during the postwar period until 1980.

The worldwide energy consumption increased during the 1965 – 73 at rates similar to those observed for the GDP. Thus, it is not surprising that during this

9-year period, the IE growth rates were near zero (Table 1). Nevertheless, some discrepancies could be observed between country groups. The LDCs, and particularly Brazil, increased their IE ratio at a rate much higher than the one measured for the DC's.

The IE level of for Latin America is higher than the LDCs average, indicating a higher level of economic development in this region (Figure 1). The case of Brazil is quite singular. The process of easy and rapid economic progress of this country, during the postwar period, followed a typically 'petroprosperity' profile due to the role played by petroleum consumption in shaping the dynamics of the economy (Furtado & Suslick, 1993). Surprisingly, Brazil had the lowest level of energy intensity during this period (Figure 1). This observation was in contradiction with the fact that the country has experienced a considerable degree of industrialization. This peculiarity of Brazilian economy was not denoting an higher energy efficiency relative to other LDCs, but was rather a consequence of the methodology used to measure the energy consumption. Brazilian industrial sector uses biomass quite abundantly. Despite the importance of this energy source, it was not included in the computation of Brazil's energy consumption. Also, the main distinguishing aspect of energy balance in Brazil is the availability of enormous amount of hydroelectricity that provides up to 90 per cent of the total supply of energy. This contrasts with the situation of other developing countries where the thermal origin prevails. This peculiarity tends to reduce the importance of electricity in the energy balance, since the international convention is the thermal conversion of hydroelectricity.[3]

Figure 1. Intensity of energy for developed countries, less developed countries, Latin America and Brazil 1965 – 90.



The aluminum, copper, and steel consumption profiles were quite different during this period. Given its properties and an aggressive marketing policy, aluminium showed a strong dynamism in the electrical, construction, and containers & packaging sectors. As a consequence, its intensity of use increased by almost 4.2 per cent during this period at the world level. The situation was quite different for copper and steel since their intensity of use remained almost stagnant during the years 1965 – 73 (Tables 2 to 4).

The 1965 – 73 period showed high aluminium IU and IP growth rates for the two considered group of countries groups. However, the growth rates for IP were higher in LDCs than in DC's. In Latin America, that rate was three times higher than the world average (Table 2). This tendency is very conspicuous and continues into the next two decades in the LDCs, chiefly in Latin America due to presence of abundant hydroelectricity and large bauxite reserves. Despite these peculiarities, the rates of growth for IU were close between DC's and LDCs, reflecting a certain convergence in the time-series patterns of consumption, even if the latter started with a lower level.

Despite the fast growth of LDCs, the DC's controlled during that period more than 75 per cent of the world aluminum production, their level doubling between 1965 and 1973 (Table 5).

The situation is quite different in the case of copper. Table 3 suggests negative growth rates for IP and IU during the 1965 – 73 period for the DC's, although IU was not falling as fast as IP. The USA, but also Chile and Zambia, were the great

Table 2. Aluminum: Growth in metal production, intensity of production, consumption and intensity of use 1965 – 90

	Average Annual Growth Rates				
	Brazil	LA	LDC	DC	World
Production					
1965 – 73	19.95	22.58	20.92	8.80	8.44
1973 – 80	13.15	20.99	11.84	3.58	3.57
1980 – 85	15.44	10.18	9.04	0.88	0.74
1985 – 90	13.62	9.53	7.76	3.54	3.78
Production/GDP (IP)					
1965 – 73	8.51	13.55	12.46	3.96	3.27
1973 – 80	5.72	14.97	6.72	1.04	0.58
1980 – 85	15.40	6.91	6.19	-2.56	-2.31
1985 – 90	11.29	7.59	4.87	0.53	0.87
Consumption					
1965 – 73	15.79	13.13	10.91	9.91	9.51
1973 – 80	8.60	7.74	13.24	2.66	3.42
1980 – 85	4.13	5.76	4.15	-0.53	-0.02
1985 – 90	4.02	2.29	8.03	2.85	2.41
Intensity of Use					
1965 – 73	5.58	6.26	4.11	4.82	4.18
1973 – 80	1.76	2.26	7.53	-0.24	0.10
1980 – 85	1.49	4.46	2.48	-2.56	-2.14
1985 – 90	1.24	0.70	4.19	-0.31	-1.03

Source: Metallgesellschaft, Aktiengellschaft Metallstatistic (several).

world producers. Thus, the IP level was higher in LDCs than in DC's (Figure 2). The IP in LDCs was much higher than IU (Figure 3), revealing the net export position of these countries. The production of copper in LDCs grew at a low rate but similar to the DC's. Labour, strikes, nationalist pressures, and the consequent reduction in investment by multinational firms explain the low production rate observed for developing countries. Although the average growth of IU was negative in DC's, LDCs showed a positive trend due to their industrialization.

The IU for crude steel rose at a faster rate in the LDCs than in DC's. This may be explained by their industrial growth, especially of their heavy industry and durable consumer goods sector. The production of crude steel increased fast in DC's and in LDCs (Table 4). However, the IP growth rate were negative in DC's. Thus, LDCs increased relatively less their steel production than DC's (Table 5). As a result of this evolution LDCs reduced the coverage of internal demand by domestic production. A similar evolution happened in Latin America and Brazil. Therefore, metals experienced a very different consumption and production growth pattern during this period of fast economic expansion. If we compare IE and IU for LDCs and DCs, we observe a more substantial difference between these country groups with steel and copper than aluminum. The building up of industry and infrastructure in LDCs seems to require more traditional metals. The evolution for IP is more complex, because of great copper export positions for the LDCs, and import substitution policies for aluminum and steel.

Energy crisis (1973 – 85) and structural changes in production and consumption of metals.

The increase of oil prices in the international market in 1973 and in 1979 (called the First and Second Oil-shock) changed the previous scenario. The world economy experienced severe modifications, and the DC's were strongly affected, remarkably on those countries with a high dependence of oil imports. Consequently, their economic growth dropped to an average of 2.7 per cent , in 1973 – 79, and to 2.07, in 1979 – 85 (Table 1). Among economists some doubts still remain whether the oil price rise has been the main cause of the GDP slowdown. Other important causes are possible such as the slowdown of productivity and international financial disorders. Despite all the controversial issues of the impact of the energy crisis, a change in the growth pattern of the industrialized economies happened that were closely related to energy consumption. The new aspect in this phase can be found in the behaviour of average growth rates of IE. The rate of growth of IE dropped briskly to -1,46 per cent and -2,60 per cent , in 1973 – 80 and 1980 – 85. This figures point out that a structural change occurred in the behaviour of economic development in the DC's, such as passage to a less intensive energy-pattern.

However, between the two oil shocks LDCs did not experienced big changes in the economic growth rates, with only a small slowdown, while maintaining the same energy-intensive pattern experienced in postwar period. The main reasons for those different economics trends between groups can be found in the facilities available for overseas borrowing in the international market. A huge amount of petrodollars, combined with low inter-

Table 3. Copper: Growth in metal production, intensity of production, consumption and intensity of use, 1965 – 90.

	Average Annual Growth Rates				
	Brazil	LA	LDC	DC	World
Production					
1965 – 73	23.28	4.90	4.08	3.67	4.21
1973 – 80	23.83	5.89	5.38	3.99	4.51
1980 – 85	27.85	3.40	4.08	0.81	0.98
1985 – 90	11.40	4.81	1.47	2.97	2.01
Production/GDP (IP)					
1965 – 73	11.78	-1.40	-2.34	-1.12	-0.87
1973 – 80	-1.30	6.13	0.86	-1.64	-1.66
1980 – 85	26.98	2.71	2.52	-1.37	-0.94
1985 – 90	6.31	3.29	-1.42	-0.23	-1.20
Consumption					
1965 – 73	20.81	7.88	6.96	4.11	4.50
1973 – 80	15.46	11.71	10.24	1.23	2.33
1980 – 85	1.48	-0.28	2.36	-0.17	-0.29
1985 – 90	-5.50	-1.48	9.72	2.17	2.43
Intensity of Use					
1965 – 73	9.94	1.20	0.25	-0.70	-0.59
1973 – 80	7.63	5.95	4.65	-1.59	-0.91
1980 – 85	-1.59	-1.75	0.70	-2.24	-2.43
1985 – 90	-7.91	-3.08	5.75	-0.96	-1,02

Source: Metallgesellschaft, Aktiengellschaft Metallstatistic (several)..

est rates by the US. Federal Reserve Bank created favourable conditions to increase the external debt of developing economies.

Thus, LDCs persisted in their previous pattern. Those countries even augmented IE from the previous period[4] (Table 1). Up to 1973 – 74 low interest rates and high exported prices led to creation of big industrial projects oriented to intermediate products and the building of infrastructures in several LDCs.

The Brazilian case is very elucidative. Despite the slowdown in the international economy, Brazil's economic and industrial expansion was maintained above Latin America and LDC average levels until 1980. Meanwhile, the rates of energy consumption were above the GDP average growth. Thus, Brazil's IE grew at a higher rate than LDCs average, due to priority given to the modern sector (heavy industry and infrastructure).

The second oil shock intensified the structural changes in DC's. There was an intensive process of technology diffusion and transformation of productive structure that had already started in the previous phase.[5] The main two reasons were an increase of energy efficiencies of equipment and changes in the sectoral composition of the productive sector. Studies about this process and their determinants in developed economies emphasize the role played by innovations based upon energy saving technologies.[6]

Meanwhile, intense transformations which took place in LDCs were heading in the opposite direction. In fact, the economic crisis that resulted from the second oil shock affected them very negatively. The capital flow stopped and even started to revert to the DC's. For example, Latin America began to export net capital during the 1980's (Rosenthal, 1990) The efforts of LDC to pay external debts were based upon primary commodities or manufactured goods exports, which real prices deteriorated seriously in the 1980's. The economic impact was negative, reducing the level of investment and consumption. As a consequence of these adjustments, the economic growth of LDCs declined sharply down to 1.64 per cent per year and even reached a level below the DC's as indicated in Table 1.

The new productive structure resulting from the adjustments of LDCs economies is one of the main reasons for the continuing growth rates of IE in the beginning of the 1980's. When comparing the data to the 1970's, a discontinuity appears: the average growth rate of IE increases from 0.68 per cent to 2.73 per cent per year (Table 1). This figure indicates that these countries followed an opposite path from that of the DC's. Latin America had the same evolution. It is noteworthy that in 1980 and 1981 the IE curves of DC's and LDCs (especially Latin America) intersected each other, illustrating a divergent path between the groups (Figure 1).

It can be seen that Brazil's showed similar trends, however with lesser intensity. The IE continue to increase, but with rates below the LDC. In response to oil shocks, Brazil almost "froze" the petroleum products consumption and in compensation the electricity consumption increased rapidly (Furtado & Suslick, 1993).

Based upon the adopted energy conversion factors, this substitution seemed to be very efficient, otherwise the results would be very different if the country electricity generation was produced from a steam source. Moreo-

Table 4. Crude Steel: Growth in metal production, intensity of production, consumption and intensity of use, 1965 – 90.

	Average Annual Growth Rates				
	Brazil	LA	LDC	DC	World
Production					
1965 – 73	11.66	7.85	3.70	4.08	5.68
1973 – 80	11.70	8.50	10.63	-1.36	0.49
1980 – 85	6.91	4.70	5.70	-1.26	0.23
1985 – 90	2.12	1.64	4.13	0.29	0.41
Production/GDP (IP)					
1965 – 73	1.73	1.28	1.73	-0.72	0.55
1973 – 80	4.37	3.22	5.52	-3.83	-2.43
1980 – 85	5.60	3.96	4.10	-3.51	-1.73
1985 – 90	0.10	-0.14	1.28	-2.63	-2.44
Consumption					
1965 – 73	18.11	10.09	13.01	5.03	5.63
1973 – 80	6.50	6.18	8.34	-1.03	1.37
1980 – 85	-0.26	-2.48	0.88	-2.48	-0.51
1985 – 90	-1.73	-0.55	5.03	2.84	1.62
Intensity of Use					
1965 – 73	7.54	3.34	5.86	0.18	0.50
1973 – 80	-0.23	0.74	2.89	-3.73	-1.80
1980 – 85	-3.17	-3.93	-0.76	-4.54	-2.64
1985 – 90	-4.20	-2.11	1.35	-0.34	-1,80

Source: International Iron and Steel Institute-Steel Institute Yearbook (several) and Statistical Yearbook (UN).

ver, the IE showed a rising profile similar with the LDC.[7]

The two oil-shocks produced strong effects in the evolution of metals production and consumption, but they resulted in divergent behaviour between country groups.

After the first oil-shock the IU for aluminium, copper, and steel grew briskly in LDCs, while in DC's these rates fell sharply (Table 2 to 4). This fact can be attributed to the economic growth that was maintained in LDCs, followed by large investment on material-intensive facilities. We can affirm that these countries maintain inalterable their previous pattern of growth. Moreover, they must have deepened this pattern by investing in heavy industries and infrastructure.

Among the DC's, the various IU's became negative for the metals studied, resulting from significant structural changes in their patterns of demand. Tilton (1990) pointed out several causes ranging from general economic slowdown and the investment policies. The technological changes seek improvements in energy-efficiencies giving priorities for the new materials use in the economy. As with high-technology goods, the demand for services and the share of services in the tertiary sector tends to rise more rapidly than the metal production sector, leading to declining IU for metals.

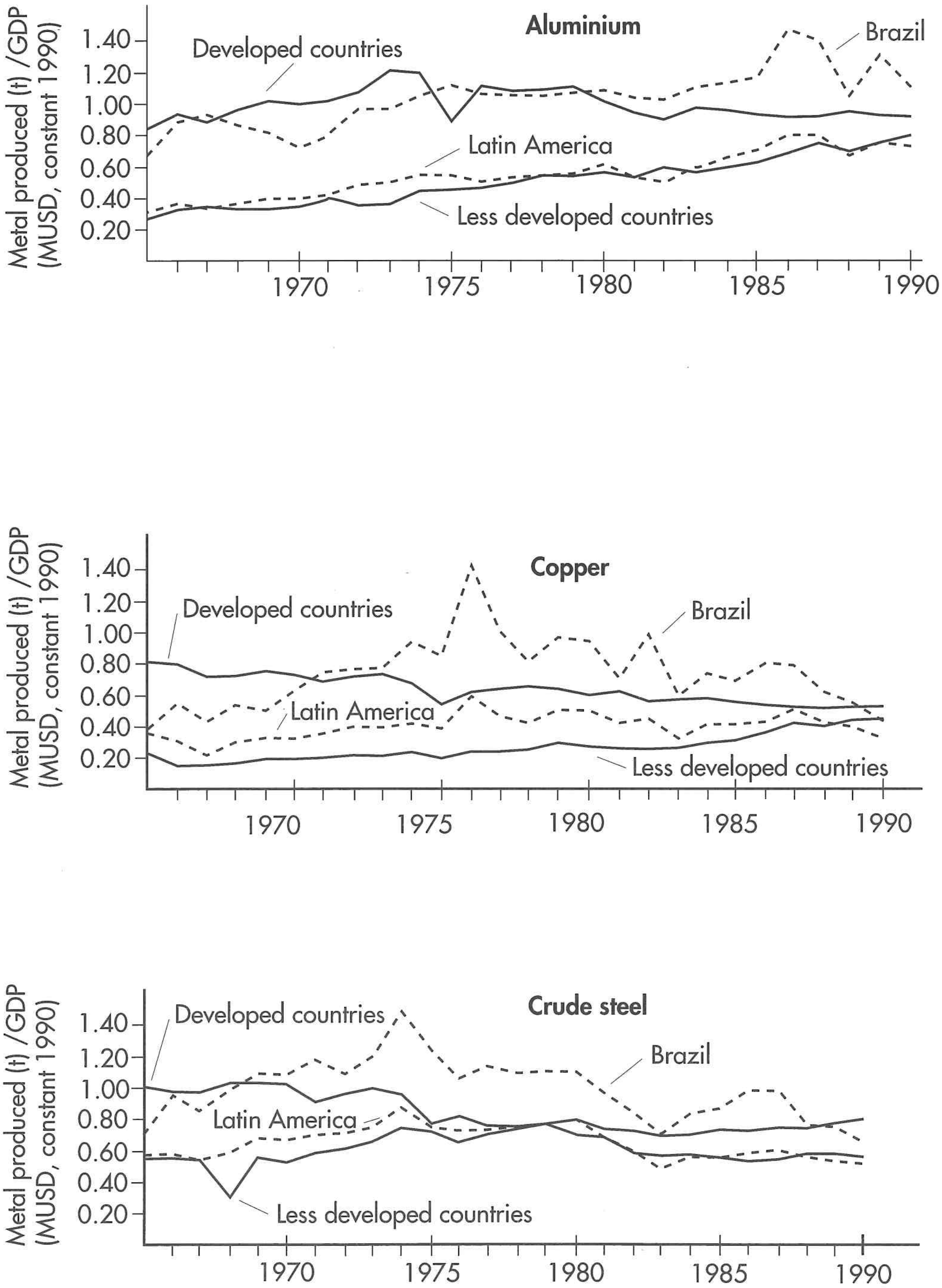
However, the observed change between the countries groups seems even more important for IP. The differences are even greater, specially when we compare Latin America and Brazil with DC's.

The two oil-shocks had a more pronounced impact on aluminum production, changing the internationally competitive levels of the industry. The hydroelectricity became a favourable comparative advantage and an important factor in the process of relocation of the aluminum industry within Brazil (Braz-Pereira, 1988). Another important aspect in the aluminum industry was the geographical shift that occurred between the six major producing countries. Australia, Brazil, and Canada had lower production costs due to favourable electric power rates for producers resulting from public investments and joint-ventures with the private sector. In Brazil, this process resulted in an increase in the aluminum production, during the 1973 – 85, from the 112 000 tons to 549,000 tons (Table 5).

However, the competitive advantage of these new exporters are not so evident if a meticulous evaluation is done. Adams and Duroc-Danner (1987) used a worldwide cost model to estimate aluminum production costs. They showed that US production costs were equivalent with costs prevailing in the LDCs, suggesting that the competitive advantage of LDCs is a matter of exchange rates and fiscal incentives, as well as the role played by the public sector.

With regards to crude steel, substantial changes occurred in this period. Deep modifications in demand structure and technological improvements in the quality of crude steel reflected in a relative stagnation of production volume on a worldwide basis. Apparently, this process affected more intensively the steel than the copper products. The decline of steel consumption in the DC's and the drop in the prices caused the shutdown of the most inefficient steel plants during

Figure 2. Intensity of aluminium, copper and crude steel use for developed countries, less developed countries and Brazil 1965 – 90.



the 1980s. For over a decade the USA adopted a restructuring program that included capacity reduction of 25 per cent and investments of US$ 10 billions for adoption of improving technologies (Souza, 1991).

After the second oil-shock, the steel IP in LDCs showed increasing rates. The case of crude steel is important because production is more widespread, than others metals, in important export-oriented regions in the LDCs. Therefore, during this period the steel industry in Brazil grew and became competitive in the international scene due to large investments made during the previous decades.

Over most of the 1980's, the industry in Brazil was shaped strongly by macroeconomic events that paralysed investments in modernization and technological improvements. One the main negative factors was a system of price controls pursued by the Brazilian government as a tool to reduce inflation rates.

The trade-off between the steel IU and IP in 1979 – 85 for the LDCs is noteworthy.[8] This trade-off can be explained by the low income levels and lack of capital resources to invest in infrastructures and equipment by heavy steel users in these countries while the uprising of IP reflected a export-oriented thrust.

For others metals great differences and important trade-offs between IU and IP can also be observed in Brazil, Latin America, and LDCs. Thus, the 1973 crisis induced a quite different trend from the two groups of countries. In DC's IE and IU dropped as a consequence of structural changes in their pattern of consumption. Meanwhile, in LDCs this evolution is the opposite: precedent trends of increasing IE and IU were reinforced. This evolution does not rely in contradiction with preference consumption argument, as they would put forward that LDCs were crossing a phase in their development where they were building up their industry and infrastructure. However, after the second oil shock the evolution become LDCs became even more complex showing specials features of the incurring changes. The IU which tended to follow investment effort of the economy dropped, while the metals production capacity was reoriented to exports.

Relative recovery of the development and the metals (1985 – 90)

This new phase was marked by the expansion of the developed economies and also some LDCs belonging to the Pacific Rim. This recovery was related to important changes in international economic setting: the depreciation of US dollar against the other major currencies and the decline of oil prices.[9] They produced an important level of international net resource flows that supported the consumption recovery and investments in European economies. The US recorded a great flow of direct investments from Europe and Japan because of exchange advantages. These financial flows also reached certain less developed Asian countries.

The GDP growth rate in DC's was higher than in 1973 – 79, although lower than in the petroprosperity period. The economic activity of the LDCs, although higher (3.7 per cent) than in 1979 – 85 (1.64 per cent), was at a lower level than prior to the second oil shock (Table 1). Latin America was not affected by these events, the average growth rates of the region, and particularly in Brazil remained similar to the first half of the 1980s.

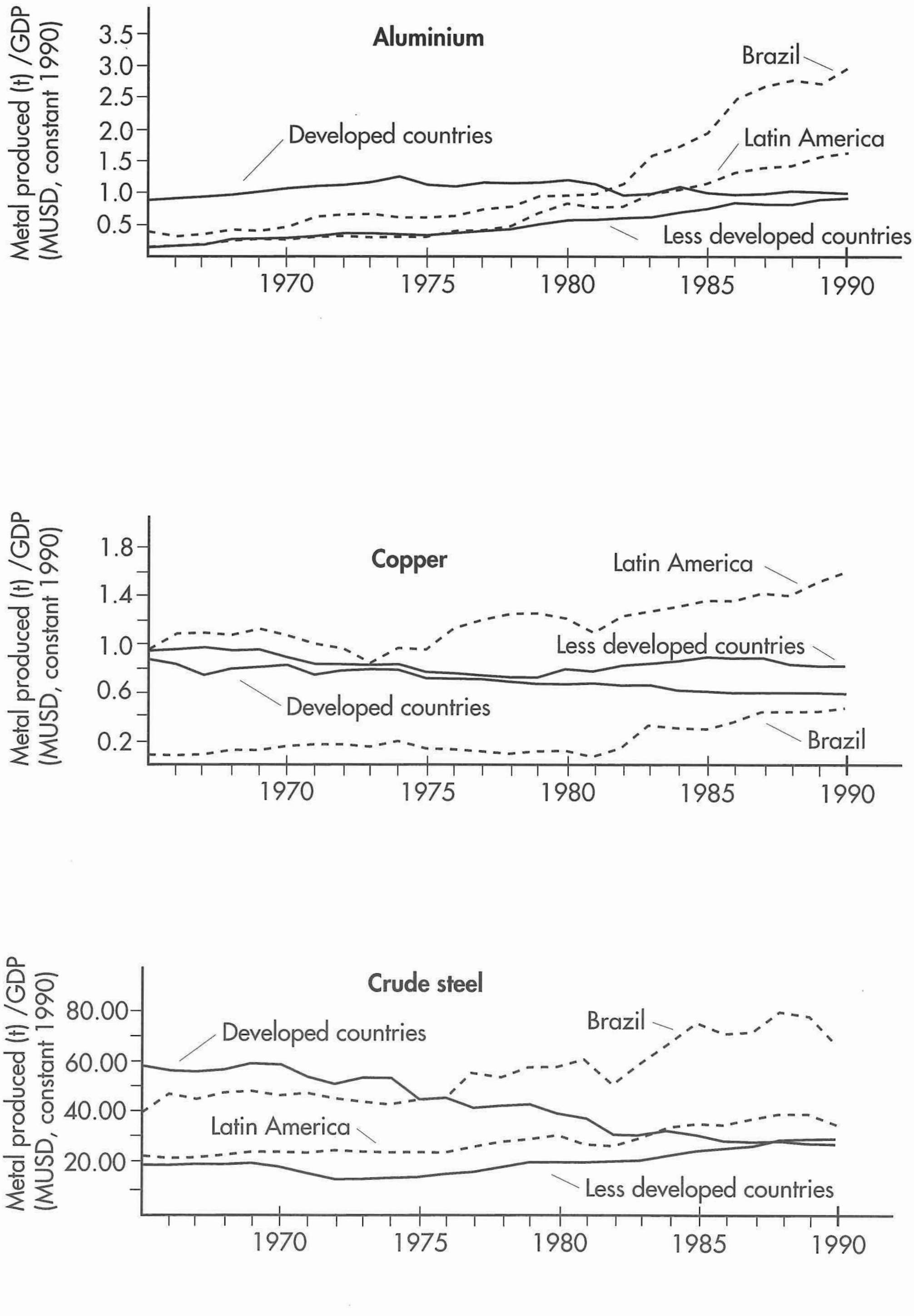
Globally, DC's maintained their reduction of the IE at a similar rate level of 1973 – 79 years. Meanwhile, LDCs showed a strong continuity in their energy-intensive path. The growth rate of IE was higher than in 1973 – 79, which is surprisingly, when we consider the relative economic recovery. In fact, the changes in the productive structure towards energy-intensive sectors were confirmed.

Table 5. Metal Consumption and Production in the Countries Groups.

	1965		1973		1980		1985		1990	
	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.
Aluminum[1]										
Brazil	51.6	29.6	157.6	111.7	284.9	260.6	323.1	549.4	341.2	930.6
L. America	126.3	52.3	333.6	227.5	584.3	819.1	697.6	1 163.6	754.6	1789.0
LDC	312.2	185.4	701.7	766.1	1 504.9	1 648.9	1 846.7	2 398.1	2 699.4	3 364.7
DC	4 945.1	5 107.2	10 3662	10 129.0	10 483.2	1 2767.5	10 720.5	12 308.1	12 318.8	14 578.7
World	**6 648.5**	**6 610.7**	**13 646.0**	**12 707.0**	**15 298.8**	**16 086.3**	**15 889.2**	**15 617.6**	**17 878.0**	**18 023.5**
Copper[1]										
Brazil	30.7	7.0	125.3	29.2	246.0	38.9	196.1	93.9	137.2	157.1
L. America	166.5	378.7	276.0	544.9	489.0	1148.4	428.2	1345.3	378.2	1697.9
LDC	307.3	1 090.3	495.1	1 491.5	820.7	2 179.4	988.9	2 657.2	1 554.3	2 855.9
DC	4 719.7	5 098.4	6 431.1	6 688.0	6 264.3	7 041.6	6 513.1	7 314.7	7 248.0	8 462.1
World	**6 192.5**	**6 197.0**	**8 739.3**	**8 525.2**	**9 389.2**	**9 270.5**	**9 612.8**	**9 723.5**	**10 820.9**	**10 733.3**
Steel[2]										
Brazil	2.7	3.0	9.5	7.1	14.3	15.3	11.9	20.5	10.2	20.6
L. America	11.6	9.0	24.7	16.4	37.3	28.9	27.7	35.8	26.7	38.3
LDC	32.2	21.7	63.1	28.5	104.9	57.5	105.1	75.7	134.2	98.5
DC	289.8	335.4	423.4	457.4	355.1	406.6	327.6	374.8	374.3	389.6
World	**452.2**	**450.6**	**697.5**	**697.6**	**719.2**	**715.6**	**723.8**	**719.0**	**783.1**	**769.6**

Notes: 1. Data in thousand of metric tonnes. 2. Data in million of metric tonnes
Source: Al and Cu Metallgesellschaft Aktiengellschaft, Metallstatistic, several, Crude steel: International Iron and Steel Institute, Steel Statistical Yearbook, various issues.

Figure 2. Intensity of aluminium, copper and crude steel use for developed countries, less developed countries and Brazil 1965 – 90.



Latin America as a group depicted a IE behaviour that represented a continuation of the 1980 – 85 period. This continuity was attributed to the effects of economic disruptions and the trade policies. Consequently, Latin America can be considered an example of productive changes, with an economic performance above the average values of developing countries.

This period was marked by the beginning of world economic recovery in the production and consumption of aluminium and copper. Almost, all this metals had a price recovery after 1987. The steel production should be considered a special case due to the existence of large stocks and also substantial technological evolution. Tilton (1990) states that the decline of steel reflected efficiency gains in their end-use products. McSweeney and Hirosako (1991) estimated that continuous casting increases the product yield by about 20 per cent and hence depresses crude steel consumption. According to the authors, it does so by reducing double counting and hence has nothing to do with final consumption.

The growth of LDC economies, mainly in the Pacific Rim, stimulated the IU of aluminum, copper, and steel. However, Latin America did not follow the same path, due to macroeconomic adjustments to reduce inflation and economic stagnation (see Tables 2 to 4).

Latin America was excluded from economic recovery during this period. Nevertheless, the IP of copper and of aluminium continued to grow, while the IU had a much lower performance. Brazil followed the same evolution. Thus, divergent trends between IP and IU were maintained for these countries (see Tables 2 to 4).

Because of the economic recovery, the LDCs returned to their previous pattern before the 1980's economic crisis, with very high level of IE and IU growth. This pattern is, of course, was quite different from DC's evolution, indicating a divergent trend between this two groups of countries between their IE and IU.

Conclusion

The energy crisis of 1973 provoked structural changes in the world economy, which extended to metal production industry as an important energy consumer. Besides that, the energy intensity (IE) declined in world basis. After 1985, the energy consumption experienced a recovery, but at a slow pace, when the GDP and energy consumption growth were not associated as in the past. We can infer that it is emerging new pattern of economic growth in worldwide scale that can be qualified as energy-saver, in opposition to the energy-intensive pattern that prevailed before 1973. This new pattern has radically intensified the dematerialisation process, which was present since the beginning of industrial revolution

Obviously, this new pattern resulted from the entrance of a new material-saving and information-intensive technologies, reflecting in the long-term metal and energy consumption trends. Newer metals with a more recent diffusion generally showed higher growth rates, while the older, more mature metals tended to decline.

However, this general trend is not observed when we analyse the IE, IU, and IP evolution in these countries groups. The energy crisis generated different patterns of behaviour in these groups for energy, as well as for metals. In the case of energy, the drop in global IE was almost a result of adjustments in DC's, while the LDCs showed an opposite rising tendency.

The metals had a more complex evolution that obliged us to make a certain distinction between the production and consumption effects. On the consumption side, the growth of IU in LDCs dissociated from DC's after the first oil-shock. Meanwhile, the economic crisis of the first half of the 1980's affected severely the majority of the LDCs, causing an interruption in IU growth. The drop of IU was due to the decreasing level of investments which was directly affected by the economic crisis. Only after the 1985, did these countries partially recovered the previous rates. However, Latin America and notably Brazil continued to present decreasing rates of IU during this period.

At the production side, IP maintained high growth rates despite the framework of economic crisis in the LDCs during the 1980s. This level of growth varied according to the extent of export-orientated regions of these countries. The impact of increased production on their energy demand is substantial, since these energy-intensive activities are growing faster than GDP.

Our aggregate analysis bring important elements to affirm that the evolution of metals and energy is not only influenced by the stage of growth (consumer preference school) or the evolution of technology over time. First, technology evolution can be considered as stochastic variable with important discontinuities that can provoke radical shifts in the patterns of demand, as a shift from an energy-intensive to an energy-saver pattern. Second, all the countries are not affected at the same level by this changes. We can postulate that LDCs, because of their weaker position in world economy, have showed a divergent pattern with DC's.

The authors are aware that the analyses carried out in the present study needs further investigation, provided suitable data can be found. For example, a complete framework to explain the divergent energy trends in Brazil as well as in the LDCs and the impacts in metals production and consumption.

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Notes

1. Levine & Meyers (1992) indicated five main causes for the rapid increase in primary energy consumption in developing countries: faster economic growth, migration from rural areas to urban areas, penetration of energy-intensive technologies, limited capability and resources to improve energy efficiency and expansion of energy-intensive industries.

2. Surely, the changes in the patterns of consumption of energy and metals are not only determined by the technological evolution. Changes in the structure of production can induce important alteration in this patterns. This change are not only provoked by the stage of growth of this countries. The diffusion of the techno-economic paradigm was accompanied by a redefinition of the commercial flows were LDCs are having a larger importance as exporter of energy and materials intensive goods.

3. The conversion used for KW is based upon its thermal value and corresponds to 0.08 Koe (Kilograms of oil equivalent). In this form to generate 1KW, 0.22 to 0.29 Koe are necessary depending of thermal plant efficiency.

4. Despite the increase were low, 0.59 per cent to 0.68 per cent , the values were significant when compared with DCs.

5. This reflected in decreasing of IE (-2.6 per cent), in 1979 – 85 period (Table 1).

6. Martin (1990) pointed out that in US, Europe, and Japan energy savings had a role two or three times larger than the changes in the productive structure in decreasing the IE. The industrial sector is the main consumer in these economies, but the services and housing consumers also show efficiency improvements , mainly in the heat system.

7. Furtado (1990) pointed out that the increase of IE in Brazilian industrial sector between 1980 and 1985 were attributed essentially to the expansion of metallurgical sector, which had not contributed to aggregate value but increased the energy consumption. The author indicated that the metallurgy sector had an expansion at the consequence of other downstream economic sector. Geller and Zylberstein (1991) showed that the industrial sector and services were the only branch that increase their IE between the period of 1973 to 1988, while the transportation and residential sectors had an inverse evolution. The authors showed in more detail the relation of energy consumption to the physical production of the important industrial sectors, indicating energy-efficiency gains in certain sectors.

8. The IP expanded (5.6 per cent) while the IU had a downward trend (–3.17 per cent).

9. This period is commonly defined as oil counter-shock effect. ■