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Public Policy and Competitiveness:

the Case of the Bauxite-Alumina-Aluminum Industry*

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Introduction

The world bauxite-alumina-aluminum industry of the beginning of the 1990s is only a dim reflection of what it was in the 1960s. Thirty years ago, the industry was growing twice as fast as the gross domestic product (GDP); today, its rate of growth is below that of the GDP. During the 1960s and early 1970s, the industry was dominated by a group of six producers, whose operations were characterized by a high degree of forward and backward integration. But the market power of the Big Six is now greatly reduced. They have to jostle for their share with second-tier integrated producers and independent bauxite, alumina or aluminum producers. Furthermore, state ownership of the western world's mining, refining and smelting capacity has constantly grown and now stands at about 30%. Thirty years ago, the peaks and troughs of demand were managed by order backlog or inventory accumulation, but as little as possible, and only as a last resort, by changes in price. Today, the LME, not producers, determines prices and price changes; prices have become less stable and much more sensitive to changes in the aluminum stocks/consumption ratio.

More importantly, the industry of the beginning of the 1990s differs from that of thirty years ago with regard to the geographic distribution of centres of production. In 1961, bauxite production in the West was dominated by Jamaica, Suriname, Guyana and France. Today, only Jamaica remains on the list of the four top bauxite producers, and it is in third place, far behind Australia and Guinea and barely ahead of Brazil. Even greater changes have occurred in the locations of alumina-producing centres. In the mid-1960s, more than 75% of western alumina production was concentrated in the G-7 countries. Today, these countries are responsible for no more than 30% of production; the main producers now are Australia, the United States, Jamaica, Brazil and Suriname. Major shifts have also occurred downstream in the geographic locations of aluminum production centres. At the beginning of the 1960s, 87% of world aluminum was produced in the seven most industrialized countries; now no more than 50% is located there. Australia, Brazil and Venezuela now hold a combined share of 20% of world aluminum production and have replaced France, West Germany and, especially, Japan on the list of top aluminum producers.

How can we explain these shifts in the locations of the western world's mining, refining and smelting activities? Are they solely the result of changes in the costs of production (energy, alumina, labor, etc.), the changes favoring new producers over older, perhaps more costly, producers? Has the shift of production to geographic zones having greater comparative advantages been facilitated or held back by the policies of the governments of the countries involved? What forms have government interventions taken? Have they been direct and specific (lower and/or more variable electrical power rates for aluminum smelters, export subsidies or levies, import quotas or tariffs, government assistance in reducing exit barriers), or indirect and general, such as changes in exchange rate relationships which favor production costs in countries with depreciated currencies, or policies with regard to regional development or respect for the environment? What are the consequences of such interventions on the economies of the countries involved? These are the questions that this article will attempt to address.

In the first section of the article, we will outline the stages of the aluminum production process and discuss the shifts that occurred between 1960 and 1990 in the geographic locations of the major activities: mining (bauxite), refining (alumina) and electrolysis (aluminum smelter). In the second section, we will attempt to explain the reasons for these shifts by examining the cost structure at each stage of the production process. We will focus not only on the main elements of cost, but also, and in particular, on the production factors the costs of which show the greatest difference from one country to another. As the countries are characterized by different factor endowments, this may help explain the shifts that have taken place. But changes in the production costs do not explain fully the shifts to new producing countries, because government interventions also play a role, by enhancing a country's comparative advantages in alumina or aluminum production, or counteracting comparative disadvantages. In the third section, we will examine the question of government interventions, both those which specifically target the aluminum industry and those which are more general and macroeconomic, affecting the industry indirectly. This section will also evaluate the effects of these government interventions on the allocation of resources in the economies of producing countries. In the last section, we will present our conclusions regarding the relation between public policy and competitiveness within the bauxite-alumina-aluminum industry.

1. Shifts in Geographic Locations of Production Centres

a) The Production Process

Bauxite is the raw ore from which alumina is extracted. Alumina can also be extracted from other ores (nepheline, alunite, anorthosite, clays, oil and coal shales), but in these cases, production costs are significantly higher. Although bauxite is globally dispersed, the main deposits are found within a belt extending twenty degrees north and south of the equator. As bauxite tends to occur in a relatively small number of large, high-grade deposits, its extraction has tended to be concentrated in a very small number of countries. It should be noted that bauxite is not a homogeneous ore, but rather a variable combination of three ores: gibbsite, goethite and boehmite. Thus, the technology of alumina production varies with the source of supply of the bauxite[1]. This creates a dependency link between the mine and the alumina refinery, a link which can be broken only at a high cost.

The second stage of the aluminum production process consists of separating alumina from the other substances which compose bauxite. This is done using the Bayer process[2]. On average, 2 - 2.5 tonnes of bauxite are required to produce one tonne of aluminum. The last stage of aluminum production is the separation of aluminum from its oxyde. This is done by means of an electrolytic process developed in the United States by Charles Hall on February 23, 1886, and almost simultaneously in France by Paul Heroult.

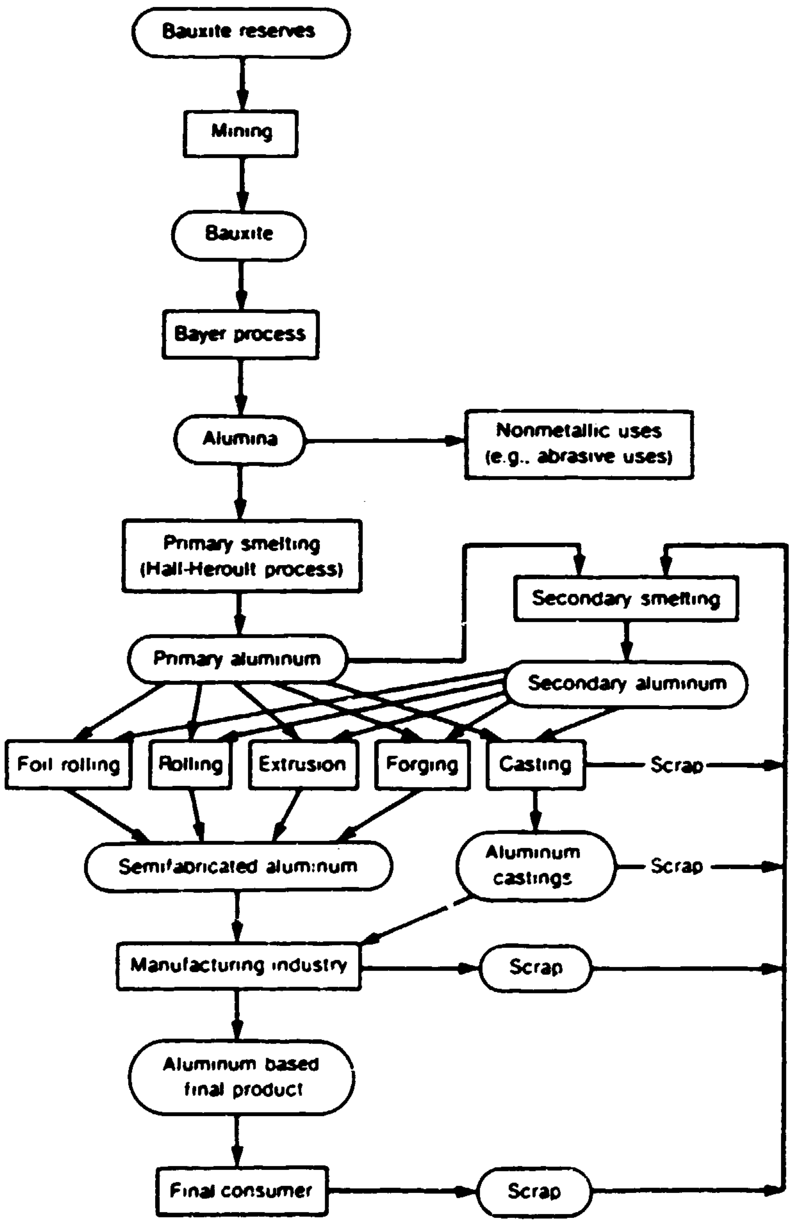
The Hall-Heroult process takes place in reduction cells or pots, which are steel boxes of various sizes lined with carbon. The alumina is dissolved in a molten salt called cryolite. Aluminum fluoride is added continuously to the molten electrolyte, in order to maintain the required density, conductibility and viscosity. Next a carbon electrode (the anode) is lowered into the solution. This causes a continuous electric current to pass through the mixture to the carbon pot lining, which acts as the cathode. Once the solution is thus electrolyzed, the dissolved alumina separates into aluminum metal and oxygen. As the aluminum is heavier, it is attracted by the cathode to the bottom of the pot, while the oxygen settles on the carbon anode to form carbon dioxide.

The molten aluminum in the pot is siphoned into crucibles and transferred to alloying furnaces, where aluminum from different pots is mixed and alloys are made. Finally, the metal is cast in an ingot mold or in molds of different forms; continuous casting of molten aluminum is also done. Although the Hall-Heroult process consumes enormous quantities of electrical energy -- about 7 kwh per pound of aluminum -- this is only half as much as was required for the same amount of production in 1930. We will later look more closely at the alumina and aluminum cost structure.

Figure 1 illustrates the primary aluminum production process which we have been describing. The figure also shows how secondary aluminum can serve as a source of supply.

Figure 1

The aluminum production process



Source:

. Peck, M.J., (1988), «Introduction» in M.J. Peck (ed), The World Aluminum Industry in a Changing Energy Era, Resources for the Future, Washington, p.5.

b) Shifts in Geographic Distribution of Production Centres

It is not usual for bauxite deposits, energy supplies and markets for aluminum-based finished products to be located in the same place. For this reason, although the aluminum industry first developed in a small number of industrialized countries, it quickly acquired (through the force of circumstance) an international character. The Alcoa company began to extract bauxite in the Caribbean in 1916. As demand for bauxite grew, aluminum companies were obliged to mine deposits located further and further away from processing plants, in such places as Africa, South America and Oceania. At the same time, requirements for reliable, low-cost energy supplies led the aluminum-producing companies to establish reduction plants in countries like Canada and Norway. And finally, the gradual but steady development of new markets for aluminum-based products in countries with rapidly-growing economies led the companies to install aluminum smelters and plants processing metal into intermediary or finished products close to these markets. There is no doubt, then, that the international character of the aluminum industry is the result of the geographic dispersion of its principal elements: bauxite mines, energy sources and markets for finished and intermediary products.

Table 1 and Figure 2 enable us to see clearly the international character of the aluminum industry, and also to pinpoint the most important shifts that have occured during the last thirty years in the locations of oauxite, alumina and aluminum production centres. Let us examine these shifts for each of the main stages of the production process.

Table 1

World production of bauxite (B), alumina (A) and aluminum (Al): 1960-1988 (in pourcentage)

	1960			1966			1975			1980			1985			1988		
	B	A[(a)]	Al	B	A	Al	B	A	Al	B	A	Al	B	A	Al	B	A	Al
AFRICA	5.7	-	1.0	5.4	3.5	0.7	12.3	2.4	2.1	16.0	2.0	2.7	17.1	1.7	3.0	18.6	1.5	3.4
Cameroon	-	.	1.0	-	-	0.7	-	-	0.4	-	-	0.3	-	-	0.5	-	-	0.5
Egypt	-	.	-	-	-	-	-	-	-	-	-	0.7	-	-	1.0	-	-	0.9
Ghana	0.7	.	-	0.8	-	-	0.4	-	1.1	0.2	-	1.2	0.2	-	0.3	0.3	-	1.0
Guinea	5.0	.	-	3.9	3.5	-	11.0	2.4	-	15.0	2.0	-	15.6	1.7	-	16.9	1.5	-
Sierra Leone	-	.	-	0.7	-	-	0.9	-	-	0.8	-	-	1.3	-	-	1.4	-	-
South Africa	-	.	-	-	-	-	-	-	0.6	-	-	0.5	-	-	1.2	-	-	1.0
AMERICA	54.3	-	56.0	51.8	52.8	49.6	31.3	38.4	36.3	28.8	37.0	40.8	20.9	28.3	38.2	21.7	29.8	40.9
Argentina	-	.	-	-	-	-	-	-	0.2	-	-	0.8	-	-	0.9	-	-	0.9
Brazil	0.4	.	0.4	0.6	0.5	0.4	1.3	1.0	0.9	4.5	1.4	1.6	6.5	3.2	3.5	7.8	4.9	5.2
Canada	-	.	15.2	-	6.1	11.2	-	4.3	7.0	-	3.5	6.7	-	3.0	8.2	-	2.7	9.0
Dominican Rep.	2.5	.	-	2.0	-	-	1.0	-	-	0.6	-	-	-	-	-	0.2	-	-
Guyana	9.1	.	-	8.2	2.0	-	5.0	1.1	-	3.3	0.9	-	2.5	-	-	1.8	-	-
Jamaica	21.1	.	-	22.1	5.4	-	15.0	8.5	-	13.0	6.9	-	7.0	4.8	-	7.4	3.8	-
Suriname	12.5	.	-	13.6	2.8	0.4	6.1	4.3	0.3	5.3	4.1	0.3	4.2	3.7	0.2	3.4	3.7	-
United States	7.4	.	40.4	4.4	36.0	37.3	2.3	19.2	27.4	1.7	20.2	29.0	0.7	10.2	22.5	0.6	11.2	22.9
Venezuela	-	.	-	-	-	-	-	-	0.4	-	-	2.0	-	3.4	2.6	0.5	3.5	2.5
Other	1.3	.	-	0.9	-	0.3	0.6	-	0.1	0.4	-	0.4	-	-	0.3	-		0.4
ASIA	5.5	-	3.5	5.9	5.9	6.1	4.3	7.6	11.0	4.8	8.4	9.8	4.3	6.0	7.4	4.6	4.0	5.8
Bahrain	-	.	-	-	-	-	-	-	1.0	-	-	0.8	-	-	1.1	-	-	1.0
India	1.4	.	0.4	1.8	1.2	1.2	1.4	1.3	1.3	1.9	1.4	1.2	2.6	1.7	1.7	3.4	1.7	1.9
Indonesia	1.4	.	-	1.7	-	-	1.3	-	-	1.3	-	-	0.9	-	1.4	0.5	-	1.1
Japan	-		2.9	-	4.5	4.7	-	5.8	7.9	-	6.4	6.8	-	4.0	1.5	-	2.0	0.2
Malaysia	2.7	.	-	2.3	-	-	0.9	-	-	1.0	-	-	0.6	-	-	0.4	-	-
Taiwan	-	.	0.2	-	0.2	0.2	-	0.2	0.2	-	0.2	0.4	-	-	-	-	-	-
Turkey	-	.	-	0.1	-	-	0.7	0.3	0.1	0.6	0.4	0.2	0.2	0.3	0.3	0.3	0.3	0.3
United Ar. Em.	-	.	-	-	-	-	-	-	-	-	-	0.2	-	-	1.0	-	-	0.9
Other	-	.	-	-	-	-	-	-	0.5	-	-	0.2	-	-	0.4	-	-	0.4
AUSTRALASIA	0.3	-	0.3	4.4	2.1	1.3	27.2	19.2	2.5	29.3	20.9	2.9	35.5	26.0	7.0	36.3	28.8	8.2
Australia	0.3		0.3	4.4	2.1	1.3	27.2	19.2	1.7	29.3	20.9	1.9	35.5	26.0	5.5	36.3	28.8	6.7
New Zealand	-		-	-	-	-	-	-	0.8	-	-	1.0	-	-	1.5	-	-	1.5

Table 1 (Continued)

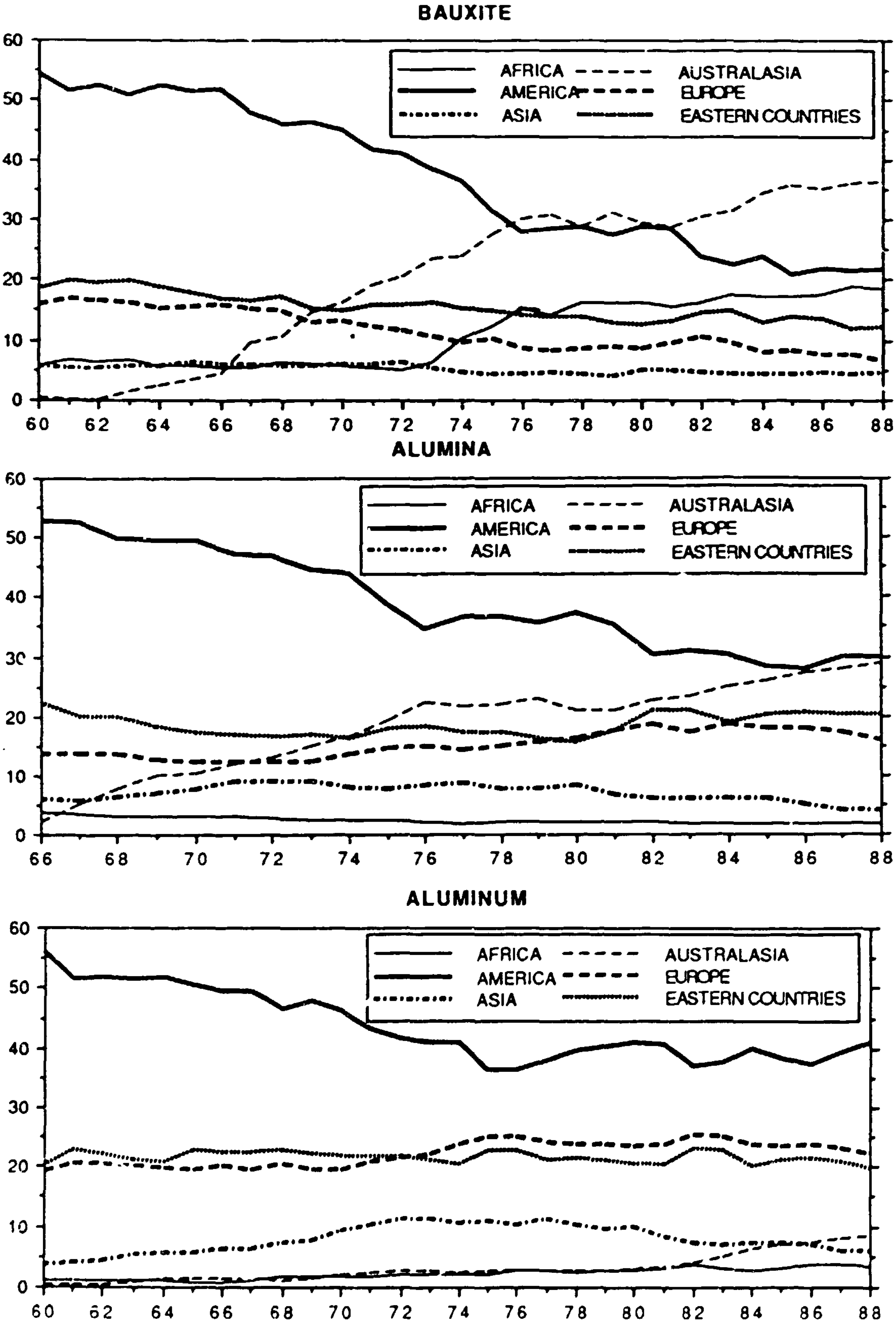
ROPE	15.7	.	19.1	15.8	13.6	20.1	10.2	14.5	25.2	8.7	16.1	23.4	8.4	17.8	23.4	6.6	15.8	22.0
istria	0.1	.	1.5	-	-	1.1	-	-	0.7	-	-	0.6	-	-	0.6	-	-	0.6
ance	7.5	.	5.2	6.8	5.7	5.0	3.3	4.1	3.0	2.0	3.9	2.7	1.7	2.6	1.9	1.0	2.0	1.9
ermany F.R.	-	.	3.7	-	4.1	3.4	-	4.7	5.3	-	4.6	4.6	-	4.9	4.8	-	3.5	4.3
reece	3.2	.	-	3.7	0.5	0.5	3.9	1.8	1.1	3.2	1.5	0.9	2.7	1.2	0.8	2.5	1.2	0.9
eland	-	.	-	-	-	-	-	-	0.5	-	-	0.5	-	-	0.5	-	-	0.5
eland	-	.	-	-	-	-	-		-	-	-	-	-	1.6	-	-	2.1	-
aly	1.1	.	1.8	0.6	1.8	1.8	-	2.6	1.5	-	2.6	1.7	-	1.6	1.4	-	1.7	1.3
therlands	-	.	-	-	-	0.3	-	-	2.0	-	-	1.6	-	-	1.6	-	-	1.6
rway	-	.	3.8	-	0.1	4.6	-	-	4.6	-	-	4.1	-	-	4.6	-	-	5.0
ain	-	.	0.6	-	-	0.9	-	-	1.6	-	0.2	2.4	-	2.2	2.4	-	2.0	1.7
eden	-	.	0.4	-	-	0.4	-	-	0.6	-	-	0.5	-	-	0.5	-	-	0.5
itzerland	-	.	0.9	-	-	1.0	-	-	0.6	-	-	0.5	-	-	0.5	-	-	0.4
ited Kingdom	-	.	0.6	-	0.8	0.5	-	0.3	2.4	-	0.3	2.3	-	0.3	1.8	-	0.3	1.7
goslavia	3.7	.	0.5	4.6	0.6	0.6	3.0	1.0	1.3	3.4	3.0	1.0	4.0	3.4	2.0	3.1	3.0	1.6
her	0.1	.	0.1	0.1	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
STERN UNTRIES	81.5	.	79.9	83.3	77.9	77.7	85.3	82.1	77.1	87.6	84.4	79.6	86.2	79.8	79.0	87.8	79.9	80.3
STERN UNTRIES	18.5	.	20.1	16.7	22.1	22.3	14.7	17.9	22.9	12.4	15.6	20.4	13.8	20.2	21.0	12.2	20.1	19.7
ina P.R.	1.2	.	1.5	1.0	1.2	1.2	1.3	1.9	2.3	1.8	2.0	2.2	2.9	3.0	3.1	2.9	3.3	3.1
echoslovakia	-	.	0.6	-	0.4	0.3	-	0.4	0.3	-	0.3	0.2	-	0.2	0.2	-	0.2	0.2
rmany D.R.	-	.	0.9	-	0.3	0.6	-	0.2	0.5	-	0.1	0.4	-	0.1	0.4	-	0.1	0.4
ngary	4.3	.	1.1	3.5	2.0	0.8	3.8	2.8	0.5	3.2	2.3	0.5	3.2	2.4	0.5	2.9	2.4	0.4
mania	0.3	.	-	0.5	0.6	0.6	1.0	1.4	1.6	0.5	1.5	1.5	0.5	1.6	1.7	0.5	1.5	1.5
S.S.R.	12.7	.	15.5	11.7	17.6	18.0	8.6	11.2	16.7	6.9	9.4	15.1	7.2	12.9	14.8	5.9	12.5	13.7
her	-	.	0.5	-	-	0.8	-	-	1.0	-	-	0.5	-	-	0.3	-	-	0.4
TAL WORLD	100	.	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0^6mt)	(27.6)	.	(4.5)	(41.1)	(14.8)	(7.2)	(77.3)	(26.7)	(12.8)	(92.8)	(34.7)	(16.1)	(89.1)	(33.8)	(15.6)	(99.6)	(36.5)	(17.2)

te
)	Publication of data on geographic distribution of world alumina production started only in 1966.

urces: Table derived from
American Bureau of Metal Statistics, Non-Ferrous Metal Data, New York, various years.
Metallgesellschaft Aktiengesellschaft, Metallstatistik, Frankfurt Am Main, various years.
World Bureau of Metal Statistics, World Metal Statistics Year Book, London, various years.

FIGURE 2

SHIFTS IN REGIONAL DISTRIBUTION OF PRODUCTION CENTRES



Bauxite

Figure 2 shows us that the market shares of world bauxite production held by America and Europe have greatly decreased, while those of Africa and Australasia have increased significantly. Between 1960 and 1988, America's share declined from 54% to 22%, and Europe's share fell from 16% to about 7%. Asia's and the Eastern Bloc's shares remained relatively stable. During the same period, the African share of world bauxite production tripled to more than 18%, while Australasia's share rose from zero to more than 36% in 1988. This is a total reversal of the 1960 situation, for at that time, Africa and Australasia's combined share was only 6%, as opposed to 55% today.

If we look at the performance of individual countries (Table 1), rather than continents or economic groupings, we see Africa's good performance is really owing to Guinea, whose share of world bauxite production rose from 5% to 17% during the period under study. Australasia's performance is entirely owing to Australia. America's relative decline is mainly explainable by the poor performance of the Caribbean countries; the combined share of Jamaica, Suriname, Guyana and the Dominican Republic dropped from 45% in 1960 to less than 13% in 1988. The decline has been particularly marked for Jamaica, which has seen its share of bauxite production cut to one-third of what it was, or barely above 7%. Hidden in the poor American figures is the good performance of one country, Brazil, whose share has been increasing since the beginning of the 1980s and is now close to 8%. Europe's decline as a producing region is mainly explainable by the decline of French production; France's current market share is quite marginal compared to what it was in the early 1960s. Greece and Yugoslavia's combined share of world bauxite production has remained constant.

With the discovery of a few large, high-grade bauxite deposits, bauxite production has become more concentrated. At the beginning of the 1960s, the four top producers (disregarding the Eastern Bloc) held 50% of the world market; three of those countries were located in Latin America (Jamaica, Guyana, Suriname) and the fourth, in Europe (France). Thirty years later, the share of the four top producers is 68%. In addition, the composition of the group has changed to now include Guinea, Australia and Brazil; only one of the former countries still remains on the list -- Jamaica.

Alumina

What shifts have occurred in the geographic distribution of alumina production centres? Table 1 tells us that in the mid-1960s, production of this fine powder was concentrated mainly in consuming countries, that is, aluminum producers. In 1966, about 60% of world alumina production was located in the seven most important industrial countries. As the share of the Eastern Bloc was 22%, no more than 18% of world alumina production took place in the bauxite-producing countries (the combined share of Jamaica, Suriname, Guyana and Australia was 12%). At the end of the 1980s, the situation was quite different. The seven most important industrial countries were responsible for only 23% of world alumina production; production had shifted towards the bauxite-producing countries, in particular those located in Australasia and South America. Asia's competitive position appeared to deteriorate after the mid-1970s, while the

European alumina industry began to decline around the beginning of the 1980s.

If we look at the locations of alumina production centres in terms of individual countries, we see that, unlike bauxite production, alumina production has tended to become less concentrated. Table 1 shows us that in 1966 the share of the five main producers outside of the Eastern Bloc was 58% (in order of decreasing importance: United States, Canada, France, Jamaica and Japan). At the end of the 1980s, the group of five main producers was responsible for only 52% of production, and the composition of the group had changed entirely. Australia, Brazil and Suriname had replaced Canada, France and Japan, and Australia (29%) has ousted the United States (11%) from the position of top alumina producer.

Australia's spectacular performance in recent years merits our attention: during the last quarter-century, this country has increased its share of the alumina market fifteen-fold. It is now the world's top bauxite (36%) and alumina (29%) producer, and it leaves second-place producers trailing far behind: Guinea for bauxite (17%) and the United States for alumina (11%). We should note that in spite of a strong overall trend towards refining on-situ, or at least within mining countries, a strong presence in bauxite production is a necessary but not a sufficient condition for a good performance in the alumina sector. Guinea and Jamaica illustrate this fact: in Guinea, alumina production levels have remained unchanged since 1966, while in Jamaica, they have not changed since the early 1970s. Access to the raw material is not enough; other factors affecting performance in the alumina sector are geographic location and transportation costs, access to low-cost energy and government policy.

To better illustrate the shift of alumina production centres from aluminum-producing to bauxite-producing countries, let us note the following: during the first half of the 1980s, new alumina production capacities valued at about 5.75 million tpy were put on stream. Of these new installations, 40% were in Australia and 30% in South America.[3] During the same period, about 5.3 million tpy of alumina production capacity was shut down; 53% of these installations were in the United States, 26% in the Far East (mainly Japan and Taiwan) and 15% in Europe. We will later consider to what extent these shifts reflect the changes in the structure of comparative advantages, which may have been enhanced or counteracted by the policies of the governments of producing countries.

Aluminum

Figure 2 shows that the American share of world aluminum production has not declined as much as its share of bauxite and alumina production. It also shows that the African and Eastern Bloc shares have remained unchanged and that Australasia's performance in aluminum has not been as spectacular as in bauxite and alumina. As for Asia, it reached its peak of 11% of the aluminum market in 1973 and 1977; after that, its share steadily declined and by the end of the period under study it was below 6%. But these aggregate figures do not show all the subtle shifts that have occurred in the relative performances of aluminum-producing countries. For this information, we must turn to Table 1, which tells us the following:

As in the case of alumina, in 1960, western production of aluminum took place mainly in the countries consuming the metal. Thus, the seven major industrial countries produced 70% of the world's aluminum (40% in the United States). Thirty years later, these countries produce just over 40% (23% in the United States). New producing countries have emerged -- Australia, Brazil and Venezuela -- whose combined share of world aluminum production is now 20%, having risen from just 1% in 1960.

Over the last thirty years, aluminum production has become less concentrated. In 1960, the six top producing countries were responsible for 71% of production; today, their combined share barely exceeds 53%. Furthermore, although the United States, Canada, Norway and West Germany remain major aluminum producers, France and Japan have been displaced by Brazil and Australia.

The dramatic decline of the Japanese aluminum industry merits some attention. After reaching a peak of 1.2 million tonnes in 1977, Japanese production dropped drastically, reaching only 35 thousand tonnes in 1988. Rarely have we seen such an important restructuring of an industry's production capacity. A decline of production capacity has also been evident, to a lesser degree, in the United States, Taiwan, the United Kingdom and West Germany. The countries that have profited from the reduction of Japanese, American and European production are mainly Australia, where production has increased by an average of 15% per year since the beginning of the 1980s, Canada, which has seen its share of the world aluminum market grow from 6.7% to 9% between 1980 and 1988, and a group of developing countries, including Brazil, Venezuela and some Arab states (Bahrain, Egypt and the UAE). These countries' production has risen from 850 thousand tonnes in 1980 to over 1.8 million tonnes today, or 10.5% of world production and 13% of the production of non-socialist countries. At the beginning of the 1990s, these countries' share can be expected to reach 17%.

How can we explain these shifts in geographic locations of bauxite, alumina and aluminum production? Are they solely the result of such factors as depletion of high-grade bauxite deposits, availability of large amounts of low-cost energy, or major changes in transportation costs? Or have the shifts in locations of production centres been influenced by the decisions of governments to play a more active role in the development of their bauxite, alumina or aluminum industries through interventions ranging from taking control of production activities to negotiating lower and/or more variable rates for energy sold by public utilities to the aluminum industry? These are the questions we will address in the following section.

2. Natural/Locational Sources of Comparative Advantages

The last three decades have seen major shifts in the geographical locations of bauxite, alumina and aluminum production centres. Thus, Australia, Brazil and Guinea have seen their share of world bauxite production increase, to the detriment of Jamaica, Suriname, Guyana and France. Alumina production has shifted from the principal industrial countries to Australia, Brazil, Suriname, Venezuela and Yugoslavia. And many aluminum smelters have shut down in Japan, the United States, France, the United Kingdom and West Germany, while new ones have been opened in Australia, Brazil and Venezuela, and more recently, in Canada and certain Arab states. How can these shifts be explained?

The usual explanation links shifts in locations of production centres to changes in countries' comparative advantages. According to the theory of comparative advantage, production and export of alumina and aluminum have increased in Australia and in Brazil, while decreasing in Japan, because their production costs relative to those of a VCR have decreased; these costs are now lower in the two southern hemisphere countries than in Japan. Thus Brazil produces and exports aluminum to Japan because aluminum production requires an intensive use of production factors (alumina, energy) which are abundant in Brazil and thus inexpensive. At the same time, Brazil imports VCRs from Japan because VCR production requires an intensive use of production factors (capital, skilled labor) that are relatively less present in Brazil and thus are more costly. In other words, VCR production in Brazil would require the use of human, capitalistic or natural resources, which, in that country, would be capable of producing more aluminum than VCRs.

This theory focuses on natural/locational sources of comparative advantage, but disregards those which are policy induced. Natural/locational sources include such factors as costs of energy and labor, the quality of mining reserves, the presence of an economic infrastructure and the legacy of past investments which can make the costs of mining, refining and/or smelting lower in one country than in another. Policy-induced sources include various government policies aimed at creating, or rather enhancing, a country's comparative advantages in the production of a good, or counteracting comparative disadvantages. Among the most common policy-induced factors are depreciation of currency in order to reduce production costs, the imposition of tariffs and non-tariff barriers in order to protect a local product against foreign competition, the allocation of hidden subsidies in order to lessen the relative importance of certain inputs, such as energy, in the total costs of production, and the adoption of less rigorous environmental protection standards in order to avoid harming the competitive position of a mining or metallurgical industry.[4]

Policy-induced sources of comparative advantages will be considered in the next section; for now, we will focus on natural/locational sources. We will look more closely at the Bayer and Hall-Herault processes in order to identify the main elements of the alumina and aluminum production function as well as the cost structure of these two products.

Figure 1 presented a very simplified scheme of the alumina and aluminum production processes. In fact, bauxite is not the only input necessary for alumina production, and alumina is a necessary but not sufficient input for aluminum production; in both cases, the production function is much more complex. Thus, the production of a tonne of alumina requires not only 2-2.5 tonnes of bauxite, but also significant quantities of caustic soda, labor, energy and other materials (in particular, lime and starch). Similarly, the production of a tonne of aluminum requires almost two tonnes of alumina, about 13,500 kwh of energy, labor, various materials (cryolite and aluminum fluoride for the reduction cells, as well as petroleum coke, pitch and anthracite coal for the anodes), a cast house and a variety of other inputs.[5]

Although a variety of cost elements and a large number of production units are involved, in order to gauge the impact of changes in the natural/locational sources of comparative advantages on the shifts in geographic locations of production, we must determine not only the relative importance of each of these inputs in the cost structure of alumina and aluminum production, but also the variance of each input from one country to another and the contribution of this variance to the variance in total costs.

Such information is not easy to obtain without access to a data bank which would give the cost in $ per tonne of alumina or aluminum production of various inputs such as bauxite, energy, labor and others in each production unit: X_{ij} (where i = 1,2,..., n is an index of the inputs and j = 1,2,. . ., m is an index of the production units). If such a data bank existed, we would be able to calculate the mean cost of input i across all plants ($\bar{X}_i = \frac{1}{m} \sum_j X_{ij}$), the mean total cost of each production unit ($\bar{Y} = \frac{1}{m} \sum_j Y_j$ where $Y_j = \sum_i X_{ij}$), each factor's share in the mean total cost of producing alumina or aluminum ($\bar{X}_i/\bar{Y}$), the standard deviation of the cost of each input (σ (X_i)) and of the total cost of each production unit (σ_y), as well as the coefficients of variation ($\sigma(X_i)/\bar{X}_i$ or $\sigma_y/\bar{Y}$).

Given that the total production cost is equal to the sum of the costs of each input, we can say that the variance of total costs can be approximated by the sum of the covariance between the total cost and the cost of each of the inputs, i.e.

$$Var(Y) = \frac{1}{m} \sum_i \sum_j (X_{ij} - \bar{X}_i)(Y_j - \bar{Y})$$

where each covariational term may be regarded as an attempt to measure the contribution of one cost element to the total variance of total cost. Thus, if we had access to such a data bank, we would be able to determine not only the relative importance of, for example, labor, in the total costs of alumina production, but also the contribution of this input to the total variation in alumina production costs. If labor were responsible for, say, 60% of the variance observed in the total production costs, we would see why countries well endowed with this factor would be likely to attract alumina production units.

However, no such data bank is available. Information of this type is collected only by producing firms' economic analysts or by consultants, and they, for good reason, are not eager to share their findings. But through a review of the existing literature and discussions with aluminum industry representatives and analysts, we have been able to sketch what we hope is quite an accurate picture of the cost structure of alumina and aluminum production.[6]

From our literature review and industry interviews, the following facts have emerged:

- If for alumina production we consider only the operating costs (excluding financial costs such as debt service and depreciation), we find that bauxite is the most important cost element, accounting for more than 40% of total direct costs. The cost of bauxite is significantly higher than that of energy (about 30%), caustic soda or labor (about 20% each) or other elements (mainly the costs of lime, red mud disposal and plant overheads).

- Given the large variety of bauxites (in terms of their recoverable alumina content and the loss of caustic soda at the digestion stage of the Bayer process), the standard deviation of cost of bauxite is greater than that of any other cost element. Furthermore, if we calculate the covariance between the direct cost of alumina production and that of each cost element, we find that the bauxite cost is the most important source of variation (more than 50%) of alumina production costs.

- For aluminum production, if we exclude the cost of the alumina (already considered) and consider only the direct operating costs, we find that energy is the most important element in the cost structure. The 40% share it represents is much greater than that of other cost elements.

- Like the cost of bauxite, that of energy varies enormously from one country to another. When the covariance between the direct cost of aluminum production and that of each of its cost elements is calculated, one finds that about 70% of variance in aluminum's direct cost is linked to energy cost.

What the above facts tell us about the international bauxite-alumina-aluminum industry is very clear. Comparative advantage in primary aluminum production lies almost entirely with access to low-cost energy, while in alumina production, comparative advantage comes with access to an inexpensive source of bauxite.

For the alumina sector, bauxite prices depend on two factors: the location of the deposit relative to that of the alumina refinery, and the quality of the bauxite. Location is important because bauxite has a low value/weight ratio; thus, freight represents a significant proportion of cost. By locating the alumina refinery as close as possible to a bauxite deposit, the producer can save on transport costs. As for the quality of the bauxite, we explained earlier that bauxite is not homogeneous, but a variable combination of three substances -- gibbsite, goethite and boehmite. Alumina producers seeking to reduce their production costs have discovered that they can increase their plants' productivity and reduce process energy requirements by modifying or entirely switching the feed from boehmitic to gibbsitic bauxites. This has increased the demand for the Australian Weipa, Guinean Kindia and Weipa and Brazilian Guyana types of bauxite (all of which are high quality, largely trihydrate high gibbsitic content, ores as well as being high grade) to the detriment of Jamaican bauxite, of which one variety (Jamaica-2 boehmitic type bauxite) represents a costly raw material for refining and smelting, and is therefore increasingly unpopular.[7]

We can thus conclude that the shifts observed over the last thirty years in the geographic locations of alumina production centres from aluminum-producing to bauxite-producing countries can be explained by the realization on the part of producers that proximity to a low cost mine gives a refinery a significant cost advantage. It is no surprise that about 70% of the alumina production capacity shut down since 1982 has been non in-situ capacity, while 85% of the new capacity put on stream has been in-situ. A number of bauxite-producing countries have benefited from this shift, but countries such as Australia, Brazil and Venezuela have benefited more than others (in particular Jamaica and other Caribbean countries). This is in part because of the physical composition of their bauxite, as North American Bayer plants have been switching from Jamaica-2 type bauxite to the higher-quality and more cheaply processed Guyana and Weipa types. Finally, we should note that reserves depletion, with the resultant loss of competitiveness, have accelerated the decline of the alumina market shares held by such former large producing countries as the United States, France, Guyana and Suriname.

If we look at primary aluminum production, we find that although the costs of labor, cryolite and fluorspar vary somewhat from one country to another, this variation has little effect on the variance in direct production costs. In fact, more than two-thirds of the direct production cost variance is owing to the cost of energy. Energy costs differ from one country to another because the cost of producing one kwh varies greatly, depending on the energy source used. According to an OECD study, the estimated cost of production in 1981 for hydroelectric power was 24 mills/kwh, as compared with 39 mills for nuclear power, 48 mills for coal, and about 66 mills for oil.[8] As countries are differently endowed with energy resources, their costs of energy production vary, and this affects the direct cost of aluminum production. In order to be competitive, aluminum producers have been obliged to shut down or refrain from increasing their production capacities in countries with high energy costs (United States, Japan, certain European countries) and to open new ones in countries with low energy costs (Australia, Canada, Venezuela and certain states in the Persian Gulf).

But, although natural/locational sources of comparative advantage are important, they do not entirely explain the geographical shifts that have occurred in the locations of alumina and aluminum production centres. The changes that have taken place in levels of aluminum production have, in some countries, been greater or lesser than would be expected on the basis of the social marginal cost of their energy. Similarly, some new alumina refineries have been established in countries relatively poor in bauxite, while other countries have seen their production diminish to a lesser extent than would be justified by their geographic location or the quality of the bauxite used. Why is the adjustment process not always in line with the changes occurring in the natural/locational sources of comparative advantage? Because some of the shifts that have taken place in locations of alumina and aluminum production have been policy induced. In the next section, we will examine in detail this other source of comparative advantage.

3. Policy-induced Sources of Comparative Advantage

At the beginning of the 1970s, the six most important companies in the aluminum industry controlled 73% of the bauxite, 84% of the alumina and 77% of the aluminum production capacity in the western world.[9] Twenty years later, as Table 2 shows us, the shares of the six Majors at each stage of the production process have declined: they now control less than 50% of the bauxite and the aluminum and 64% of the alumina production capacity. These companies now have to share their control of the industry with a whole row of other private producers, as well as with state enterprises.

State control of the western world's bauxite, alumina and aluminum production capacity now stands at about 30%, which represents an increase from a decade ago (between 20% and 25%). We are speaking here of control as defined in Table 2, not of ownership defined in terms of equity holdings. State ownership of mining operations, as described in the latter definition, is even greater, hovering around 40%.

However, we believe that neither definition adequately reflects the influence governments are able to exert on the industry.

Table 2

Ownership (O) and Control (C) as Percentage of Western World Capacity at the Bauxite Mining (B), Alumina Refining (A) and Aluminum Smelting (Al) Stage, 1980-1990[a]

	1980						1985						1990					
	O			C			O			C			O			C		
	B	A	Al	B	A	Al	B	A	Al	B	A	Al	B	A	Al	B	A	Al
6 Majors[b]	47	61	53	61	69	52	36	55	48	52	67	50	34	53	43	49	64	46
Other Majors[c]	10	3	5	10	3	7	17	9	11	17	7	11	16	9	11	17	7	10
Other Private Companies	8	22	27	8	14	24	12	17	23	10	8	20	11	14	25	8	5	21
Total Private Control[d]	62	78	75	75	79	74	63	74	74	75	74	72	59	71	71	72	69	68
State Control	38	22	25	25	21	26	37	26	26	25	26	28	41	29	29	28	31	32
Total Western World	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Notes

(a) Ownership of mining, refining or smelting capacity is calculated from the shares of equity held by the participants in an operation. For the major aluminum companies ownership is traced back from both direct and indirect ownership in a mine, refinery or smelter.
Control is calculated by following these four basic rules:
- i) full control is allocated to a company holding more than 50 % of the equity shares of an operation;
- ii) full control is also allocated to a company in a situation where the company holds 50 % or less of the equity and is the major shareholder amongst a number of other companies and other partners not directly participating in the bauxite/alumina/aluminum industry;
- iii) in a consortium of joint venture between two or more companies in which no one company holds more than 50 % of the equity or no one firm is obviously in control, control of the operation is allocated in proportion to the equity share-holdings;
- iv) in cases whereby a company or group of companies own less than 50 % of shares in a mining venture, an alumina refinery or in a smelter, while the state is the majority shareholder but is not obviously in control, additional information on e.g. voting power, company supply systems, offtake commitment, etc, is used to determine control.

(b) Alcoa, Alcan, Reynolds, Kaiser, Pechiney and Alusuisse.

(c) Billiton and Comalco in the cases of bauxite mining and alumina refinery and Alumax, Billiton, Comalco and VAW in the case of aluminum smelting.

(d) Being state-owned companies, Pechiney's and/or VAW's capacity has been excluded from the percentage of «total private control» but included in the percentage of Western World capacity controlled by the 6 Majors or the Other Majors companies.

Sources: Table derived from:

- Kalpoe, Ramesh, «Ownership and Control in the World Bauxite Industry, 1980-1990», IBA Review, (July-September, 1986), pp. 16-24.
- Kalpoe, Ramesh, «Ownership and Control in the World Alumina Industry, 1980-1990», IBA Review, (January - March, 1987), pp. 15-22.

This influence can take more subtle forms than control or ownership: it can be in the form of direct or hidden subsidies, prices control, financing infrastructure costs or a deliberate depreciation of currency. Before we examine the methods chosen by governments to influence the relative costs of production and thus induce changes in the structure of comparative advantages, let us look at Table 3, which gives a non-exhaustive list of the reasons invoked by governments in order to justify interventions, and the techniques they generally use. This analysis grid will help us to evaluate the policy-induced sources of comparative advantage in the international bauxite-alumina-aluminum industry.

In economic literature, government intervention is justified in the case of a market failure. There are three main sources of market failure: imperfections in the market structure (natural monopoly, destructive competition, etc.), insufficient information, and the presence of externalities. In order to counteract these causes of failure, government authorities have recourse to a whole panoply of intervention instruments aimed at regulating production, consumption or distribution activities or inciting economic agents to change their behavior.

The international bauxite-alumina-aluminum industry has not been spared government interventions in its activities, and since the beginning of the 1970s, these interventions have been increasing. Many reasons have been put forward to justify them. In several bauxite and/or alumina-producing countries, government authorities have claimed that they lacked information about the structure of production costs and the dynamic of transfer prices between the branches of integrated multinational firms, and have chosen to obtain that information by themselves becoming producers.

Table 3

Commonly Used Techniques for Correcting Market Failures

Intervention Techniques	Sources of Market Failure: Imperfect Market Structure — Natural Monopoly	Imperfect Market Structure — Destructive Competition	Insufficient Information	Externalities
Command and Control				
- Price Control	X			
- Entry Regulation	X	X		
- Standard Setting				
. Prohibitions			X	X
. Design				X
. Performance				X
- Disclosure of information			X	
- Antitrust Enforcement	X	X		
- Rate of Return Regulation	X			
Incentive Measures				
- Competitive Bidding for Business Licenses	X			X
- Taxes, Fees	X[a]			X
- Public Expenditures and Subsidies			X	X
- Bargaining			X	X
Other measures				
- Partial of total nationalization	X		X	
- Public Enterprise			X	

Note

[a] In the case of excessive rents or profits

Sources: Table derived from:

- Breyer, Stephen, «Analyzing Regulatory Failure: Mismatches, Less Restrictive Alternatives, and Reform», Harvard Law Review, January 1979, pp. 459-609, and
- Lévesque, Robert, «Cadre d'Analyse de la Réglementation» («Analytical Framework of Regulation»), Institute of Applied Economics Research Papers, Ecole des Hautes Etudes Commerciales, IEA-88-03, Montreal, May 1988, p.30.

They have totally or partially nationalized the mining or refining operations on their territories, or created parallel state enterprises responsible for establishing new operations, either alone or in joint ventures.[10] Other countries, unhappy with their lack of negotiating power in relation to a local monopoly or an international oligopoly, have tried, in consultation with the International Bauxite Association, to establish minimum prices for bauxite and alumina, as well a mechanism for indexing those prices to that of primary aluminum. The most commonly-used intervention technique has been the extension of subsidies to attract aluminum companies into a country in order to profit from their positive externalities and the fallout from their investments on the regional economies. Thus, some countries have offered companies discounts on electricity rates for specific time periods, while others have offered variable rates for energy, with the rates usually being linked to the price of primary aluminum, so that risk is shared between state and producer.

Let us examine more closely the government policies aimed at inducing changes in the structure of countries' comparative advantages at each stage of the aluminum production process. We will begin with policies which have been created specifically for the industry under study.

a) Lower and/or Variable Electrical Power Rates for Aluminum Smelters

In the preceding section we established that the cost and availability of electrical energy are the main determinants of the location of aluminum smelters. Recognizing this fact, governments of countries endowed with abundant supplies of inexpensive energy chose in the past to sell energy to the aluminum industry at rates equal to or even below average costs, in order to attract new production capacities onto their territories and thus stimulate economic and industrial development. However, the energy crisis of the mid-1970s put a brake on this practice, as preoccupation with economic development gave way to concern about energy conservation. The aluminum industry now came to be perceived not as a factor for development, but as a taxation vehicule, a source of revenue to be gained as energy prices increased at a faster rate than production costs. Long-term contracts were renegotiated and aluminum smelters in the north-western United States saw their energy rates of 2-3 mills/kwh rise ten-fold. The increases in rates for electricity, water royalties and other forms of taxes which occurred in most aluminum-producing countries were aimed at making the industry pay for each kwh it used a price that was closer to the true cost of energy generation and distribution. During this period, we saw the almost-total shutdown of the Japanese aluminum industry and the closures of some smelters in the United States and in few European countries.

The next major change in the industrial and economic policy of aluminum-producing countries took place in 1982. As a result of the recession that was experienced in all western economies, as well as a decline in aluminum's intensity of use index, aluminum prices fell dramatically to a level that barely covered the average costs of the most efficient producers. In addition, large projects (construction of hydro-electric dams, nuclear power stations, etc.) that were launched in the mid-1970s in order to stimulate energy supply were reaching completion at the same time as energy demand experienced a cyclical slump, which left public utilities with excess production capacity. Again governments looked to the aluminum industry to be a lever of economic development. But now they were obliged to operate in a different context from that of a decade earlier, a context of partnership, which recognized the aluminum industry's cyclical nature, as well as its need to have energy cost represent as stable as possible a percentage of its average long-term costs. The aluminum industry, for its part, had to recognize that although the average variable cost of most energy producers is relatively low (5-15 mills/kwh), the marginal cost of generating an additional kwh in the long term by harnessing new rivers or construcing new nuclear power stations is manifestly higher, even if in the short term there is an energy surplus. The average variable cost alone, without considering the long term marginal cost of energy, is not an adequate base upon which to fix the rate paid by the aluminum industry, especially if the opportunity cost of the energy-- its possible use if it is not sold to the aluminum industry -- is high.

It is in this historical context that we should consider the use of energy as a factor for increasing a country's comparative advantage or counteracting its comparative disadvantage in aluminum production. Energy can be used for this purpose in two different ways: by granting short-term discounts on the usual electricity rates in order to attract new investments and make use of energy surpluses, and by negotiating variable rates in order to prevent the closure of smelters or even encourage reopenings. Let us examine the two approaches in turn.

We know that once a capital investment has been made for the construction of a hydro-electric power dam or a coal-fired or nuclear station, the incremental cost of operating this capacity is quite low; in the case of a hydro-electric dam, the variable costs represent 5-8% of the total short-term costs. We can imagine the pressure that is exerted on authorities responsible for public utilities to increase energy consumption as much as possible; by stimulating sales, they have the potential of covering not only their variable costs, but also a part if not all of the fixed costs. The pressure becomes even greater when, owing to an over-estimation of demand, the utility finds itself with an excess energy production capacity. There is then strong incentive to sell energy at discount, not only to help cover an increasing percentage of the fixed costs, but because the opportunity cost of the surplus is almost zero.

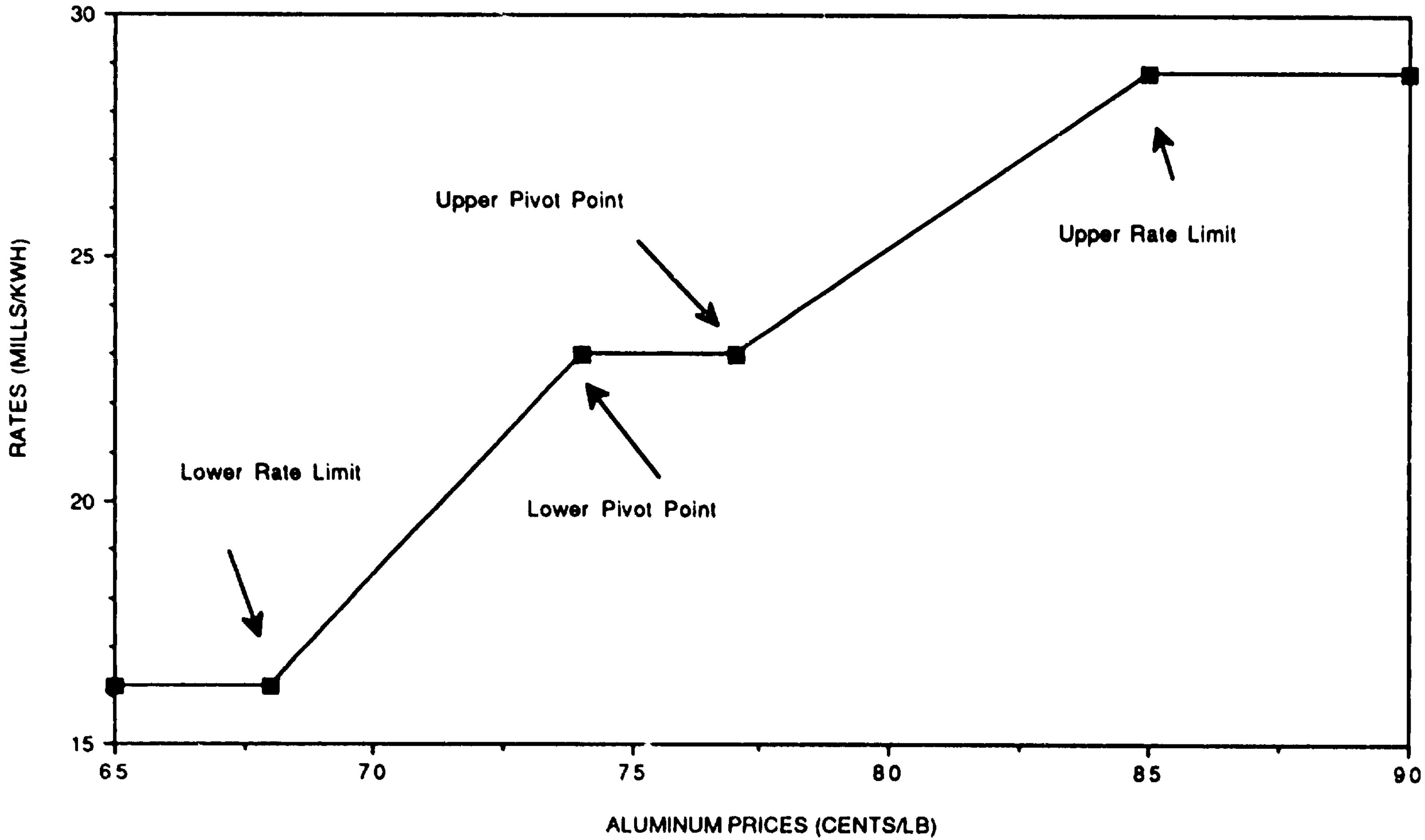
Such energy discounts have been granted by countries considered to possess a comparative advantage in aluminum production (Australia, Brazil, Canada), in order to attract new aluminum investments and benefit from the positive externalities generated by these projects (especially their effects on the regional economy). In Canada, the Quebec government decided to make better use of its energy surpluses, which were assessed in 1984 at more than 50 twh, and cut at least in half the long-term rates for the first five years of operation of new aluminum smelters. Such discounts always serve as strong incentives, because they help increase a company's cash flow during a project's first years, which is a particularly critical period for a capital-intensive investment. Quebec authorities justified the discounts they offered on the basis that if the surpluses were not sold, the excess hydro capacity would remain idle and water would probably be spilled; they also claimed that they had no choice, as their competitors in Australia and Brazil were offering equally attractive discounts to bring in new investments.

We should note that these discounts and other forms of government subsidies are not always given openly; they sometimes take on rather subtle forms. Thus, a public utility may decide that the rate charged to aluminum smelters for electricity will be based on the normal cost of service criterion when the price of aluminum is "normal." However, if we ask aluminum market analysts what is the "normal" price of aluminum, we get a wide range of responses. If the public utility considers as normal a very high aluminum price (let us say $1.50/lb., a price reached on only one or two occasions), then the rate charged by the energy suppliers will be below the normal cost of service, which is equivalent to a direct subsidy. Often cited as an illustration of this form of subsidy is the Portland smelter case in Australia. Brazil has also sold energy at discount to aluminum producers located in its north-eastern regions. In Brazil, it was agreed that while the energy price will vary in relation to its production and distribution costs, it will not surpass a certain fixed percentage of the price of the good produced by the consumer.[11]

Sales of energy at discount for short periods of time have now become less common, as excess energy capacity has decreased. The approach also proved unpopular. The non-industrial energy consumers were not accepting that the discounts were being granted without any conditions, with no requirement that the operators of the new smelters contribute to the financial health of the public utilities when the upswing of the economic cycle brought higher aluminum prices and profits. The subsidies proved particularly frustrating in cases when local or foreign energy demand proved higher than originally anticipated during the subsidy period, and thus the opportunity cost of the energy sold at discount to aluminum producers increased.

To avoid these difficulties, some public utilities have introduced the concept of market risk sharing, which recognizes that consumers' ability to pay for their energy varies over time, being low in periods of recession and much higher in periods of economic expansion. These utilities have brought in a system of variable energy rates for the aluminum industry, in which the rate is linked to the price of aluminum. There are a number of examples of this practice, but the best known is that of the Bonneville Power Administration (BPA), which introduced variable rates for electricity on August 1, 1986, in order to discourage aluminum smelter closures in the near term, encourage higher smelter operating rates and increase revenues above those otherwise expected (the BPA's revenues from sales to aluminum smelters had declined by one-third in 1986, to $200 million below the 1985 level).[12] The conceptual BPA rate, as effective July 1, 1989, is outlined in Figure 3.

FIGURE 3
BONNEVILLE POWER AUTHORITY
VARIABLE POWER RATE EFFECTIVE JULY 1, 1989[a]



Note : (a) The variable industrial rate pivot points are defined as follows:
Upper Rate Limit: power rate 28.8 mills/kwh - aluminum price 85.1 cents/pound.
Upper Pivot Point: power rate 23.0 mills/kwh - aluminum price 77.4 cents/pound.
Lower Pivot Point: power rate 23.0 mills/kwh - aluminum price 74.8 cents/pound.

The figure shows a non-linear relation between the price of power (measured in mills/kwh) and the aluminum price (cents/lb), which can be summed up as follows: As long as the aluminum price is between 74.8 cents/lb (the lower pivot point, LPP) and 77.4 cents/lb (the upper pivot point, UPP), the BPA will sell its electricity to aluminum producers at 23 mills/kwh. If the aluminum price goes above the UPP, for each increase of 1 cent/lb, the electricity rate will go up by about 0.75 mill/kwh, up to a ceiling of 28.8 mills/kwh for a price of 85.1 cent/lb or more for aluminum. The compensation mechanism is not really symmetrical, because for an aluminum price below the LPP, the power rate decreases by 1 mill/kwh per 1 cent/lb decrease in the aluminum price. The floor price of the power is 16.2 mills/kwh, corresponding to an aluminum price of 68 cents/lb; should the aluminum price go even lower, the electricity rate will not drop.[13]

The BPA is not the only public utility to offer some of its clients a variable energy rate mechanism. Hydro-Quebec offers a similar mechanism, the details of which are not made public. We know, however, that the average rate offered to aluminum producers in 1989 was about 80-85% of the published rate for power-intensive industries, or about 17-18 mills /kwh. Two other aluminum-producing countries which offer variable rates for energy are Iceland and Ghana.

What should we think of this practice? Although it offers certain advantages -- there is less need to constantly renegotiate electricity rates, new and existing smelters are assured that energy prices will remain affordable in the foreseeable future, and there are beneficial effects on the regional economy -- variable rate charging also entails some disadvantages. There is not only the difficulty of determining the pivot points (which requires an always-debatable definition of what constitutes an adequate rate of return for a public utility and an accepatable price for aluminum producers), but also the possible impact of the variable energy rates on the structural characteristics of the industry. Like other forms of government intervention, variable energy rates interfere with the industry's adjustment process in situations of excess supply. If firms have access to artificially low rates for their energy, the closing of uneconomic smelters is delayed, which prolongs the state of disequilibrium. This exacerbates cyclical price volatility, for in order for producers to get rid of excess supplies, prices must decline by a larger percentage than they would have had the market been left to find its equilibrium without hindrance. In addition, if aluminum prices are more volatile than those of aluminum substitutes, consumers will prefer the substitutes, which will further affect the long-term profitability of aluminum producers. In sum, the variable rate practice can provide short-term solutions to problems specific to a given region, but in the long term, it may amplify the problems of the industry as a whole.

What about subsidies or discounts on energy granted for limited periods of time? They can be justified in the short term, because the variable costs account for just a small share of the total production costs, and because in situations of excess capacity, the opportunity cost of the energy sold at discount becomes almost zero. In addition, by increasing a new smelter's cash flow during the first years of operation, these discounts make the project more bankable. However, what is justifiable in the short term may not be in the long term, and for that reason, a policy of offering discounts on electricity rates for a set period of time is not advisable.

The energy situation is capable of changing very quickly, and this affects the energy's opportunity cost. Thus, a greater-than-anticipated increase in the demand for energy in Quebec and the north-eastern United States, combined with limited rainfall during the last few years, has increased the opportunity cost of the energy sold by Quebec to aluminum smelters, all the more so as Quebec has available to it a most attractive export market.[14] The same can be said of Brazil, which because of an increase in internal consumption, owing to industrialization, and limited rainfall during recent years, must now import energy from Paraguay to satisfy demand. This increases the opportunity cost of sales made to aluminum plants for the time period during which the discounts apply. Another problem with discount sales is that the discounts may influence the long-term price of the energy sold to aluminum factories. This can happen if once the period of discount is over, the price of energy does not return fully to a level covering the long-term marginal social cost. Such a policy may bring more energy-intensive industries into a country and will probably result in less energy efficiency than when electricty prices more closely reflect the costs of production.

Contents of the last 20 - 25 pages:

b) Export levies and the International Bauxite Association

c) Environmental Legislation and Comparative Costs

d) Exchange Rates and Production Costs

e) Other Policies

- influence of state control
- adjustment policies and exit barriers

Conclusion

Notes

1. Bauxite ores can be classified into three distinct groups, for which there are three corresponding types of processing technology. Monohydrate bauxite, which is usually found as boehmite in France, Greece, Hungary, Italy, Turkey, the USSR, Yugoslavia and Northern Asia, is transformed into alumina using the European version of the Bayer process. Trihydrate bauxite is found as gibbsite in Suriname, Guyana, Guinea, Ghana or Australia; it is processed using the American version of the Bayer process, which requires lower temperatures than the European version and uses a less concentrated caustic soda. The third type of bauxite is the Jamaican type, which is characterized by a mixture of gibbsite and boehmite. This bauxite, located mainly in the Caribbean (Jamaica, Haiti, Dominican Republic) is processed using a method which combines elements of the European and American processes.

2. The Bayer process can be described as follows: Dried, ground bauxite is mixed in a large digester vessel with a solution of caustic soda. The soda allows the aluminum oxide, which is subjected to strong pressure, to dissolve, while impurities such as iron oxide and silica remain in a solid state and are separated from the aluminate solution by washing and filtration under pressure. Then the sodium aluminate liquor is seeded with hydrated alumina crystals. The seeds attract the crystals and form groups which are heavy enough to settle out of the solution. The alumina hydrate crystals are then calcinated in long rotary kilns, where the very high temperature rids them of water. What remains is calcinated aluminum, a sort of white powder resembling a fine salt which, in the final stage of the process, is transformed into aluminum metal.

3. The others were in Europe, in particular, in Aughinish in Ireland and in San Ciprian in Spain, in neither of which is any bauxite extracted.

4. For a more detailed discussion of this approach and its application to the North American aluminum, copper, nickel, lead and zinc industries, see Nappi, C., (1989), "Changing Patterns and Determinants of Comparative Advantage in North American Metal Mining," <u>Resources Policy</u>, Vol. 15, No. 1, pp. 24-44.

5. For more detailed technical information about alumina or aluminum production, see:
   Chase Econometrics (1982), <u>World Aluminum: Retrenching and Restructuring</u> (Bala Cynwyd, Pennsylvania; Chase Econometrics Associates), pp. AL-102 and AL-103.
   Stamper, J.W. and H.F. Kurtz (1975), "Aluminum," in <u>Mineral Facts and Problems</u> (Washington; U.S. Department of Interior), p. 59.

6. In addition to interviews with aluminum industry representatives, the following documents were used:

   Anthony Bird Associates, Aluminium Annual Review (Surrey, United Kingdom, various years);
   Chase Econometrics, World Aluminum: Retrenching and Restructuring (Bala Cynwyd, Pennsylvania, February 1982), pp. AL-100 to AL-132;
   Commodities Research Unit Limited, Competitive Strategy in Aluminium (London, United Kingdom, 1989);
   Hilyard, M., "State of the Bauxite/Alumina/Aluminium Industry and Outlook," IBA Quarterly Review, (September-December, 1987), pp. 24-37.
   London Metals Research Unit Ltd., Annual Review of the World Aluminium Industry, Shearson Lehman Brothers (London, United Kingdom, various years);
   Resource Strategies Inc., Limitations on Expanding World Primary Aluminum Smelter Capacity, (Exton, Pennsylvania, August 1989);
   Springborn Laboratories and Philipp Townsend Associates, Inc., The Impact of Energy Costs, Technological Change and Capital Equipment Costs Upon Raw Materials Competition: 1980-1985-1990 (Enfield, Connecticut, and Houston, Texas, undated), Chap. 8.

7. Often cited in the literature is the Reynolds' Sherwin Plant in Corpus Christi (Texas), which has increased its capacity from 1.4 million tonnes of alumina to 1.7 million tonnes per annum by switching its feed from Jamaica-2 type bauxite to Trombetas (Guyana type) and Sangaredi (Weipa type) bauxites. For more detail, see:

   V.G. Hill and S. Ostojic, "The Prospects for Changes in Regional Bauxite Production Patterns in the Late 1980s to Early 1990s," IBA Quarterly Review (October-December 1984), pp. 24-31.

8. Organization for Economic Co-operation and Development, Aluminium Industry: Energy Aspects of Structural Change, (Paris, 1983), Table 7, p. 112.

9. Charles River Associates Inc., Policy Implications of Producer Country Supply Restrictions: the World Aluminum-Bauxite Market (Cambridge, Massachusetts, 1977), pp. 72-75-77.
   Charles River Associates Inc., An Economic Analysis of the Aluminum Industry (Cambridge, Massachusetts, March 1971), pp. 3-50.

10. A lack of information would prevent government authorities from judging to what extent the transfer prices used among subsidiaries of multinational firms reflect the true costs of production and whether declared profits adequately serve as the base for the imposition of taxes. By nationalizing these subisidiaries totally or partially, or by putting into place a reference sector, the authorities believe they enable taxes and royalties to better reflect the opportunity cost linked to the use of their non-renewable natural resources.

11. For more information about Australia's and Brazil's aluminum industry policies, see:

    Beggs, John J., "Australia: One Day in the Sunshine," in Merton J. Peck (ed.), The World Aluminum Industry in a Changing Energy Era (Resources for the Future, Washington, 1988), pp. 121-147.
    Braz-Pereira, Eliezer, "Brazil: the Transition to an Export Industry," in Merton J. Peck (ed.), op. cit., pp. 148-174.

12. The BPA supplies power to smelters in the Pacific North-West, which represent about 40% of United States aluminum production capacity.

13. The levels of the pivot points were not chosen at random. The upper pivot point corresponds to the long-term operating costs of the highest-cost producer in the region served by the BPA. Considered here are not only the usual costs of operation, but also the corporate overheads and an allowance for sustaining capital expenditures. The lower pivot point corresponds to the short-term avoidable costs of the highest-cost aluminum smelter in the Pacific North-West, i.e. only those costs which would be "avoided" in the event of a shutdown. Finally, the floor price is supposed to reflect the energy's opportunity cost to the BPA; initially set at 15 mills/kwh, the floor price is supposed to vary with time.

14. The average price of the energy sold by Quebec to the north-eastern United States is about 30 mills/kwh, far above the prices offered to the aluminum industry (around 17-18 mills/kwh).