The Developing Economies, XXIV-2 (June 1986)

ECONOMIC DEVELOPMENT EFFECTS OF AN INTEGRATED IRON AND STEEL WORKS: A CASE STUDY OF MINAS GERAIS STEEL IN BRAZIL

TAEKO TANIURA

I. INTRODUCTION

BRAZIL is a newly emerging industrial country that has reached international standards in the fields of iron and steel production, shipbuilding, and automobile production. To a large extent such industrial development on its part has been possible because of the availability of quality steel plate and sheet in large quantities and at low prices.

As its level of national income has risen, its iron and steel consumption has also increased. The "steel intensity curve" [3, pp. 7–10] is an indication of the empirical truth that steel consumption (the ratio of apparent steel consumption to GNP) continues to increase up to the point where real per capita GNP (in terms of prices in 1963 dollars) reaches U.S.$2,000. Per-capita steel consumption in developing countries is much lower than in advanced industrial countries (roughly 50 kilograms versus 500 kilograms a year). In Brazil's case, the increase has been from 41 kilograms in 1961 to 116 kilograms in 1980[1] as a reflection of rise in demand for steel products along with the development of heavy industry. In 1980 Brazil's crude steel production reached 15.3 million tons, and it is now self-sufficient in this field with the exception of special steel products.

Minas Gerais Steel (Usinas Siderúrgicas de Minas Gerais, S.A., USIMINAS) is one of the integrated iron and steel plants that were constructed after 1955 for the purpose of supplying flat steel products during the early days of Brazil's active heavy industrialization drive. Japan has contributed to the construction and operation of the USIMINAS works in both economic and technological terms through a semi-governmental company established as a capital participant in the project. The purpose of the present paper is to demonstrate, on the basis of a case study of USIMINAS, that (1) the forward linkage effect has promoted

This paper is based on my field work conducted in 1982 as part of the research project of I.D.E. on "Evaluation of Japanese Economic Cooperation to Developing Countries." I am fully indebted to Messers Antônio José Neves Pinto and Domingos Sávio Dias Ferreira of USIMINAS, and Mr. T. Kashibuchi of Nippon USIMINAS for their sincere cooperation to my study. Thanks are also due to Prof. Y. Torii of Keio University, Prof. K. Yoneda of Toyo University, and Mr. H. Sakai of I.D.E. for useful comments on an earlier draft of this paper. Any remaining errors are my responsibility.

[1] Estimate based on [18, Table V] for population and [7] for apparent steel consumption.

the development of industries that use iron and steel products as input materials, (2) the backward linkage effect has stimulated the activity of industries that provide the iron and steel industry with raw materials and services, (3) the import substitution effect has saved foreign exchange, and (4) the employment effect has created jobs, all of these effects contributing to the country's economic development. However, owing to space limitations, it has been possible to treat the foreign exchange saving effect and the employment effect only by indicating the actual results in the conclusion. Furthermore, in connection with the general observation that the production cost of iron and steel products in developing countries tends to be higher than international prices owing to higher machinery and equipment, the question is considered whether or not the cost of protection of domestic iron and steel production in Brazil is greater than in the United States, where the iron and steel industry is already a declining industry owing to high wages.

Section II deals with the development of the flat steel processing industry in Brazil, Section III with the cost of protection of flat steel production in Brazil estimated on the basis of production cost, Section IV with the economic development effects, and the appendix with econometric techniques of estimation of such effects.

II. DEVELOPMENT OF THE FLAT STEEL PROCESSING INDUSTRY

USIMINAS' iron and steel production is important to the production activity of Brazil's industry. USIMINAS' flat steel products are used for 80 per cent of the country's railway-car production, 70 per cent of its packing material and container production and 60 per cent of its production of automobiles and automobile parts, ships, bicycles and two-wheel automotive vehicles, and industrial machinery. In 1980, 26 per cent of USIMINAS' flat steel products was used for automobiles and automobile parts, ships, and railway cars, 7.4 per cent for packing materials and containers, 7 per cent for agricultural and industrial machinery, 6.5 per cent for electrical and electronics machinery, 3.1 per cent for civil engineering and construction materials, and 16.9 per cent for secondary processing, and the remaining 33.1 per cent was supplied to flat steel product consumers through the wholesale sector.

Table I gives the row totals for the inverse coefficients of the input-output table. The row totals for the total inverse coefficients ($\sum_{j=1}^{n} B_{ij}^{c}$) represent the production inducement effects of USIMINAS products and import products of the same kind. The production inducement effect of USIMINAS is 2.17, which means that USIMINAS has to increase its production by 2.17 units or supply 2.17 units of imported products of the same kind to its demand sectors in order to meet final demand when there is a 1-unit increase in final demand in all of Brazil's industries. This production inducement effect of 2.17 is not all that great when compared with the figure of 3.78 for pulp and paper

TABLE I

FORWARD LINKAGE EFFECTS BY INDUSTRIAL SECTOR, 1970: ROW TOTAL OF INVERSE COEFFICIENT

	$\sum_{j=1}^{n} B^{c}_{ij}$ (1)	$\sum_{j=1}^{n} B^{d}_{ij}$ (2)	$\sum_{j=1}^{n} B^{c}_{ij} - \sum_{j=1}^{n} B^{d}_{ij}$ (3)	Leaks (%) (3)/(1)
1. Agriculture	3.85	3.59	0.25	6.65
2. Mining	1.99	1.50	0.48	24.46
3. Ceramics	1.57	1.50	0.07	4.50
4. Iron & steel except USIMINAS	3.82	3.47	0.35	9.38
5. USIMINAS	2.17	2.14	0.02	0.99
6. Non-ferous metal	2.25	1.80	0.45	20.00
7. Metal processing	1.86	1.73	0.12	6.81
8. Industrial machinery	2.69	2.36	0.33	12.43
9. Electric and electronics machinery	1.99	1.78	0.20	10.11
10. Transportation machinery	1.60	1.53	0.06	4.31
11. Wooden products and furniture	1.37	1.34	0.02	1.50
12. Pulp and paper products	3.78	3.11	0.67	17.81
13. Rubber products	1.72	1.60	0.12	6.96
14. Leather and leather products	1.16	1.16	0.00	0.29
15. Chemical products	6.27	5.19	1.08	17.29
16. Fiber and fabrics	2.06	2.00	0.05	2.82
17. Apparel and shoes	1.00	1.00	0.00	0.05
18. Food	2.58	2.47	0.11	4.29
19. Beverage and tobacco	1.13	1.11	0.02	2.02
20. Printing and publishing	5.35	4.89	0.46	8.67
21. Other manufacture	2.92	2.68	0.23	7.95
22. Electricity	2.70	2.52	0.17	6.54
23. Water services	1.00	1.00	0.00	0.03
24. Civil engineering	1.13	1.11	0.01	1.53
25. Commerce	5.78	5.33	0.44	7.75
26. Transportation	2.78	2.42	0.35	12.83
27. Communication	3.29	3.07	0.22	6.83
28. Finance	23.30	21.11	2.18	9.39
29. Other services	13.04	11.85	1.18	9.10
30. Unclassifiable	2.65	2.39	0.26	9.82
31. Total	108.94	98.91	10.03	9.21

products and 6.27 for chemical products, but the fact that only 0.99 per cent of such production inducement effect depends on imports (i.e., the leakage rate is only 0.99 per cent) is an indication that USIMINAS products (the row total for the domestic inverse coefficients: $\sum_{j=1}^{n} \mathrm{B}^{d}_{ij}$) account for almost all of such production inducement effect. Although the production inducement effects of pulp and paper products and chemical products are high, the leakage rates of the forward linkage effects of those industries are also a high 17.8 per cent and

TABLE

FORWARD LINKAGE

	Agriculture 1	Mining 2	Ceramics 3	Iron and steel except USIMINAS 4	USIMINAS 5	Non-ferrous metal 6	Metal processing 7	Industrial machinery 8	Electric and electronics machinery 9	Transportation machinery 10	Wooden products and furniture 11
1. Agriculture			40		1880		1077	331	229	389	
2. Mining			6		192		120	23	23	39	
3. Ceramics			733		861		138	20	20	37	
4. Iron & steel except USIMINAS			4		221		164	20	26	30	
5. USIMINAS			1		62712		53	4	6	16	
6. Non-ferrous metal					6		4	1	1	2	
7. Metal processing			24		70724		77476	105	117	183	
8. Industrial machinery			65		21602		7485	13566	1038	1636	
9. Electric and electronics machinery			104		22100		3179	282	20439	338	
10. Transportation machinery			202		187150		15721	1038	2062	187124	
11. Wooden products and furniture			43		3838		3832	91	87	174	
12. Pulp and paper products			7		309		177	48	43	66	
13. Rubber products			8		476		336	54	48	77	
14. Leather and leather products			4		246		225	11	11	20	
15. Chemical products			187		5547		3869	585	525	933	
16. Fiber and fabrics			33		1482		1013	150	156	277	
17. Apparel and shoes			27		2141		1807	141	138	244	
18. Food			249		19504		17175	1158	996	1890	
19. Beverage and tobacco			166		2267		1858	139	126	206	
20. Printing and publishing			8		407		258	53	49	80	
21. Other manufacture			39		2457		2006	147	271	241	
22. Electricity			3		339		74	8	273	16	
23. Water services			8		376		216	59	53	77	
24. Civil engineering			7123		92254		63871	1104	5406	1757	
25. Commerce			91		12845		9403	179	416	4056	
26. Transportation			179		16878		5062	726	961	11402	
27. Communication			1		133		27	3	50	65	
28. Finance											
29. Other services			25		3474		1359	102	421	1919	
30. Unclassifiable			42		2073		1063	377	316	481	
31. Total			9418		534494		219049	20525	34307	213773	

II
MATRIX FOR USIMINAS

(Cr$ 1,000)

Pulp and paper products 12	Rubber products 13	Leather and leather products 14	Chemical products 15	Fiber and fabrics 16	Apparel and shoes 17	Food 18	Beverage and tobacco 19	Printing and publishing 20	Other manufacture 21	Electricity 22	Water services 23	Civil engineering 24	Commerce 25	Transportation 26	Communication 27	Finance 28	Other services 29	Unclassifiable 30	Total 31
												4							3950
												1							403
																			1810
																			464
																			62792
																			13
												2							148631
												5							45397
												3							46444
												7							393305
												2							8066
												1							650
												1							1000
																			517
												11							11657
												2							3114
												2							4499
												20							40992
												2							4764
												1							856
												2							5163
																			712
												1							790
												22366							193882
												2							26992
												261							35469
												1							280
												1							7301
												5							4356
												22703							1054269

17.3 per cent, respectively, which means that there is considerable increase in imports when final demand for such products increases in various domestic industries.

Table II shows the quantities of USIMINAS iron and steel products used directly and indirectly by the different industrial sectors of the Brazilian economy in 1970 in meeting final demand. For instance, the figure of Cr$15,721,000 in column 7 of row 10 indicates the amount of USIMINAS iron and steel products needed for the increase in production in metal-processing industries induced by increase in the final demand for transportation machinery. The final demand for transportation machinery also induced Cr$1,038,000 of production of USIMINAS iron and steel products through the industrial machinery sector, Cr$2,062,000 through the electric and electronics machinery sector and Cr$187,124,000 through the transportation machinery sector.

As can be seen in Table II, USIMINAS products were used in a wide range of industries, and 70 per cent of such production was induced by final demand in the transportation machinery sector (row 10), the civil engineering sector (row 24) and the metal processing sector (row 7). In other words, it was possible to achieve import substitution with respect to the final demand of those three sectors because of the availability of USIMINAS products. Half of USIMINAS' production is consumed by the company itself (as raw material input for production of steel plate and sheet from pig iron and crude steel), and the remaining half is used by the metal processing sector (column 7), the transportation machinery sector (column 10), the electric and electronics machinery sector (column 9), the civil engineering sector (column 24), the industrial machinery sector (column 8), and the ceramics sectors (column 3) as a supporting factor of their production activity.

So far we have considered the situation in 1970. Looking at 1980, we see considerable increase in the strength and extent of USIMINAS' forward linkage effects, the reason being diversification of use of hot-rolled and cold-rolled steel sheet produced by the company as a result of further change of the industrial structure in the direction of heavy industrialization thanks to promotion of import substitution in energy, capital goods, and intermediate goods by the Second National Development Plan (1974–79). Furthermore, the value of imported goods used per unit of industrial production declined by 1980 to 59.8 in capital goods sectors (industrial machinery, electrical machinery, and transportation machinery) and 47.7 in the iron and steel sector against an index of 100 for 1970, which means that considerable import substitution has been taking place and that the industrial base is being strengthened (Table III).

Flat steel production by USIMINAS has played a considerable role in the development of Brazil's flat steel processing industries, particularly the shipbuilding industry and the automobile industry. In 1964 USIMINAS steel plate received "A" grade certification in the Lloyd's ship classification, which opened the way to development of the Brazilian shipbuilding industry. Up to then Brazil's shipbuilding tonnage had been only about 60,000 tons, but by 1980 it reached 1.2 million tons. Thanks to production by USIMINAS, the country was 80 per cent

TABLE III

IMPORT PER UNIT OF INDUSTRIAL PRODUCTION (INDEX)

	Total Import[a]	Capital Goods[b]	Intermediate Goods				Fuel & Lubricant Oil	Consumption Goods[a]
			Organic Chemistry	Iron & Steel	Non-ferrous Metal	Others		
1970	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1971	104.7	110.6	103.8	188.8	105.1	81.1	106.1	137.3
1972	110.2	127.5	136.3	150.4	112.9	105.6	108.3	145.9
1973	124.9	108.0	138.5	213.7	126.6	87.2	123.6	149.5
1974	125.9	140.1	115.1	449.6	155.1	106.4	115.6	178.8
1975	115.2	143.9	86.4	292.2	119.1	82.2	115.4	123.0
1976	122.3	107.3	120.1	101.9	112.4	92.6	120.3	151.5
1977	116.6	80.7	93.9	82.3	132.3	110.1	116.0	154.3
1978	125.1	73.9	95.1	59.2	105.7	99.9	120.3	142.6
1979	120.0	66.9	95.1	45.6	110.1	100.6	123.8	131.1
1980	111.2	59.8	75.8	47.7	101.8	104.1	103.6	125.2

Sources: For import input by sector, [1, Table VI-18], and for GNP and industrial production index, [4].

a Import per unit of GDP.

b General, electrical, and transportation equipment.

self-sufficient in shipbuilding steel plate by the early 1970s, and today it is nearly entirely self-sufficient in that field except for some special steels [10, p. 17]. Up until about 1975 USIMINAS had a 90 per cent share of the market for shipbuilding steel plate, and even today its share has remained above 60 per cent.

Production of passenger cars in Brazil started about the same time as establishment of USIMINAS (1958). In those days passenger car production was about 2,200 vehicles compared to total automobile production, including buses, trucks, jeeps, etc., of about 35,000 vehicles. In 1965, when USIMINAS started producing steel sheet for automobiles, passenger car production increased to about 103,400 vehicles, and total automobile production to about 185,000 vehicles. Since then production of automobiles has continued to increase in step with expansion of USIMINAS' production capacity. In 1975, when first-phase expansion of the company's production facilities was completed, boosting production of hot-rolled and cold-rolled, steel plate and sheet, it reached 929,800 vehicles, and in 1980, when the company's steel sheet production capacity attained 2 million tons with 80 per cent completion of the phase three expansion program, it reached the figure of 1,164,174 vehicles [12].

Besides steel plate and sheet for shipbuilding and automobile production, the company has developed new products to meet new needs, and it has also improved the yield rate in the steel plate and sheet processing processes for higher productivity. For example, by producing steel plate with guaranteed tensile strength, it has made possible lighter machinery and steel structures and reduced production costs. Other examples of new products it has developed are high-tensile-strength steel sheet with good weldability, corrosion-resisting steel sheet for welding applications, steel sheet for porcelain enamelling, steel sheet with high processing performance for automobiles, etc. USIMINAS produces ordinary steel sheet with a tensile strength of 40–50 kg/mm^2 and high-tensile-strength steel sheet. Brazil can now produce 70 per cent of the 50 kg/mm^2 steel plate that it needs for shipbuilding, marine structures and pipelines, and its technological level in this respect is comparable with that of Japan and Italy, with which it competes.

III. COST OF PROTECTION OF FLAT STEEL PRODUCTION

A. *Production Cost: A Comparison with Japan*

The Nippon Steel Corporation was in charge of the basic design of the USIMINAS production facilities and has continued to provide the company technical assistance since commencement of its operations. That is why USIMINAS is on a comparable technological level with Japanese integrated steel plants of the same scale (Nippon Steel's Yawata, Muroran, Kamaishi, and Hirohata works) in terms of production per worker, the coke rate, the fuel rate, the continuous casting rate, and the yield rates for the different products. Only in terms of production per unit of time is it a bit behind the Japanese plants owing to differences in machinery and equipment [19, p. 121]. Accordingly the unit physical inputs of raw materials, labor, etc. can be considered to be about the same, and by multiplying such unit inputs by the unit prices, one can compare the costs of production of steel plate and sheet in the two countries.

Cost of raw materials and cost of labor. Since Brazil has considerable iron ore resources, the price of iron ore there is only 70 per cent of its price in Japan (the ratio of the f.o.b. price at a Brazilian port and the c.i.f. price in Japan). On the other hand, since Brazil has to import coal from distant fields in North America, the price of such imported coal is 20–30 per cent higher than the price of coal to Japan (the comparison this time being between the two c.i.f. prices). The overall cost per ton of flat steel products of these main raw materials taken together is therefore roughly the same for the two countries. The cost of labor, however, to the Brazilian iron and steel industry is only about half of the cost to its Japanese counterpart, wages, benefits and recruitment, and training expenses included.[2] Assuming that the cost of auxiliary raw materials and other expenses are the same for the two countries, the production cost per ton of flat steel products is lower in Brazil's case to the same extent as the cost of labor is lower than in Japan.

Capital costs. In the way of capital costs, both depreciation costs and interest costs are higher to USIMINAS than to Japanese iron and steel manufacturers. Furthermore, since, as already mentioned, the amount of production per unit of time is lower in the plate making and hot-rolling processes at USIMINAS than in Japan because of differences in machinery and equipment, the construction cost per unit of production of an integrated steel plant in Brazil is higher than

[2] Estimate based on [20, 1978, 1979, 1980 editions] [21] [14, 1981, 1982 editions].

in Japan even assuming that the apparent plant and equipment construction cost is the same in both countries.

Construction cost. Generally speaking, the construction cost of integrated steel plants tends to be higher in developing countries than elsewhere because of high transportation costs due to the fact that such countries are dependent on imports of machinery and equipment. USIMINAS has been no exception in this respect. Both in the initial construction of its integrated steel plant and its first two subsequent phases of expansion 75–80 per cent of the machinery and equipment was imported. Although about 70 per cent of the machinery used in the third phase of expansion (1977–83) was domestically produced [10, p. 42], construction costs were even higher than before owing to the low productivity of the Brazilian machinery manufacturing industry: an estimated U.S.$1,500 per ton of crude steel production capacity versus U.S.$648 in the second phase of expansion (1972–76) [10, p. 37]. Such construction costs were higher than those in Japan during the same period. For instance, in the case of the Ōgishima plant of Nippon Kokan, built in 1971–79, the construction cost was about U.S.$650 per ton of crude steel production capacity [15, p. 119].

Interest burden. The interest burden in Brazil is heavy because of the high rate of inflation. Because of a high percentage of dependency on foreign-exchange financing (22.7 per cent for the first phase of expansion, 27.3 per cent for the second, and 25.5 per cent for the third), the interest burden has increased with decline in the exchange value of the cruzeiro. In the early seventies USIMINAS' financing costs were less than 10 per cent of its total sales, but as a result of the subsequent decline of the cruzeiro they rose to 20 per cent in 1981 [21] and 25–26 per cent in 1982,[3] versus a figure of about 7 per cent for the Japanese iron and steel industry [2].

According to data furnished by flat steel product consumers, the prices of USIMINAS' flat steel products are 20–30 per cent higher than international prices, which is understandable from the above analysis indicating that its higher capital costs more than offset its lower labor costs.

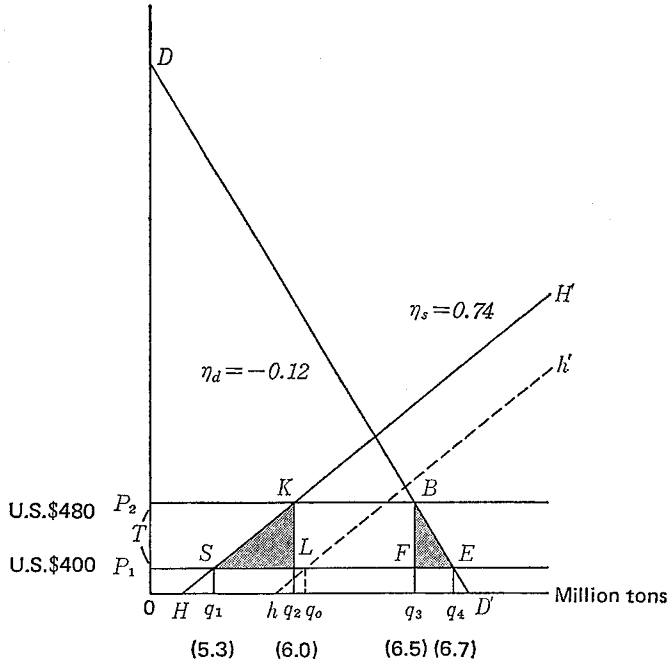
B. *Cost of Protection*

USIMINAS and other Brazilian flat steel product manufacturers are protected by severe restrictions on imports of such products, and as a result, the Brazilian flat steel processing industry is forced to use input materials that are more costly than those of foreign competitors, preventing cost reduction and hindering efforts to expand exports. The Brazilian automobile manufacturing industry, which consumes 20 per cent of USIMINAS' flat steel products, has managed to absorb such cost of protection by improving its technology and raising its productivity, but the shipbuilding industry, which consumes 5 per cent, is still laboring under this burden.

A comparison with the U.S. iron and steel industry, which is already on the decline because of high labor costs, will give an idea of the extent of the burden

[3] According to information supplied to author by USIMINAS.

Fig. 1. Consumer Cost of Flat Steel Product, Brazil, 1980



Source: Author's estimates.

imposed on Brazilian flat steel product consumers by protection of that country's production in that field. The analysis is based on Corden's concept of the "cost of the investment in learning"[4] of infant industries.

The burden imposed on Brazilian flat steel product consumers. In Figure 1, *HH'* is Brazil's present flat steel product supply curve. Imposition of a tariff *T* shifts the domestic production from q_1 to q_2. The cost of production exceeds the import cost by △*SKL*. Furthermore, the tariff increases the burden on consumers by △*FBE*. These two costs represent Corden's "cost of investment in learning" of an infant industry. By this investment in learning it is hoped that Brazil's flat steel product supply curve will shift to *hh'* and that production will increase to q_0, for which it is necessary that the marginal cost of production be equal to the import price, that the average cost of production be lower than the import price and that the burden on consumers during the infant industry stage (△*FBE* and △*SKL*) can be covered. The flat steel product demand curve *DD'* has a low price elasticity of −0.12, and the "burden on consumers" (△*FBE*) part of the consumer surplus is only 0.05 per cent. Furthermore, the flat steel product supply curve *HH'* also has a low price elasticity of 0.74, and △*SKL*,

[4] W. M. Corden calls this "the cost of investment in learning," i.e., a cost for protecting infant industries [5, p. 267].

TABLE IV

EQUATIONS FOR ESTIMATING THE PRICE ELASTICITY OF FLAT STEEL SUPPLY AND DEMAND IN BRAZIL

1. Price elasticity of flat steel demand:

$$\log Q_d = -1.20 - 0.12 \log P_d + 1.80 \log \text{GDP}.$$
$$\quad\quad (-0.089) \quad (-1.92) \quad\quad (5.76)$$

Figures in parentheses are t-statistics.

Coefficient of autocorrelation (first order)	0.21390
R^2 corrected	0.99993

2. Price elasticity of flat steel supply:

$$\log \frac{Q_s}{L} = -3.92 + 0.74 \log P_s + 0.19 \log \frac{K}{L}$$
$$\quad (-1.83) \quad (1.67) \quad\quad (1.33)$$
$$-0.15 D'^{74} - 0.17 T.$$
$$(-0.72) \quad (-1.95)$$

Figures in parentheses are t-statistics.

Coefficient of autocorrelation (first order)	0.007416
R^2 corrected	0.99757

where

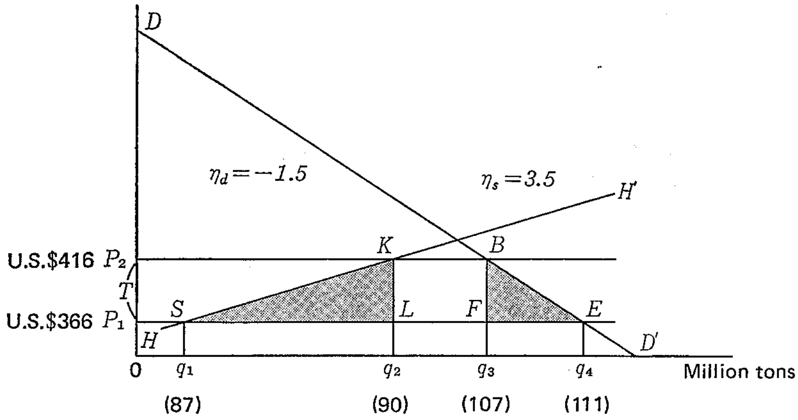
Q_d: Apparent flat steel consumptions;
P_d: Flat steel shipment price;
GDP: Gross domestic product;
Q_s: Production of hot metal (iron);
L: Number of workers in steel industry;
P_s: Price for shipping steel ingot;
K: Annual investment in steel industry;
D'^{74}: Dummy variables, 1974=1, other years=0;
T: Time trend.

the excess of cost of production over the import cost, is also only 0.23 per cent of the consumer surplus. Accordingly, one can conclude that the cost of protection of Brazil's flat steel product production is only 0.3 per cent (Table IV) because of the low price elasticities of both demand and supply.

The burden on U.S. steel product consumers. The United States has in the past adopted trigger prices with a view to restoration of its iron and steel industry, and presently it has de facto import restrictions in the form of voluntary export restrictions on the part of other countries. Since U.S. steel demand, production, and imports are all far greater than those of Brazil, the U.S. price elasticities of demand and supply are a high −1.5 and 3.5, respectively. Since the nominal protection rate is also only 13.6 per cent of international prices, which is lower than in Brazil's case, the cost of protection is only 0.22 per cent of the consumer surplus (Figure 2).

As indicated above, the cost of protection of the iron and steel industry is very low in both Brazil and the United States (0.3 per cent and 0.22 per cent, respectively, of the consumer surplus), and therefore the cost of protection as the cost of the investment in learning of an infant industry can be considered to be justified in Brazil's case.

Fig. 2. Consumer Cost of Steel Products, the United States, 1978



Source: Estimated from data by R. W. Crandall [6].

IV. ECONOMIC DEVELOPMENT EFFECT

A. *Procurement of Input Materials*

USIMINAS gets its iron ore from the Itabira Mine at a distance of about 100 kilometers and its manganese ore and dolomite from areas around Belo Horizonte, the state capital, some 225 kilometers away. Part of its coking coal is imported from the United States and transported by railroad from the port of Vitoria, and the rest is procured domestically from the state of Santa Catarina, again by railroad. Procurement of input materials and services by USIMINAS induces production activity on the part of Brazil's raw material and service industries, and its repercussion effect on the Brazilian economy as a whole can be estimated by determining the column total of the inverse coefficients of the input-output table for 1970.

For USIMINAS the column total of the total inverse coefficients $(\sum_{i=1}^{n} B_{ij}^{c})$ is 3.78 (Table V), which means that for every unit of increase in production of iron and steel products by USIMINAS, Brazil's economic activity (imports included) increases by 3.78 units. Only the pulp and paper products has a greater backward linkage effect (4.35) than USIMINAS. If imports are excluded from USIMINAS' procurements of raw materials, its backward linkage effect $(\sum_{i=1}^{n} B_{ij}^{d})$ comes to 3.54. In other words, imports are induced to the extent of only 0.24 units. This can also be expressed in terms of a low-leakage rate of the backward linkage effect of USIMINAS' production activity of only 6.52 per cent as an indication of it low dependence on imports, which in turn is a reflection of its efforts to economize on imported coking coal by making tech-

TABLE V

BACKWARD LINKAGE EFFECTS BY INDUSTRIAL SECTOR, 1970: COLUMN TOTAL OF INVERSE COEFFICIENT

	$\sum_{i=1}^{n} B^{c}_{ij}$ (1)	$\sum_{i=1}^{n} B^{d}_{ij}$ (2)	$\sum_{i=1}^{n} B^{c}_{ij} - \sum_{i=1}^{n} B^{d}_{ij}$ (3)	Leaks (%) (3)/(1)
1. Agriculture	1.88	1.79	0.09	4.91
2. Mining	1.79	1.72	0.07	4.16
3. Ceramics	2.49	2.31	0.17	7.10
4. Iron & steel except USIMINAS	3.43	3.18	0.25	7.48
5. USIMINAS	3.78	3.54	0.24	6.52
6. Non-ferrous metal	3.15	2.62	0.53	16.91
7. Metal processing	2.86	2.61	0.25	8.84
8. Industrial machinery	3.20	2.77	0.43	13.44
9. Electric and electronics machinery	3.35	2.65	0.70	20.96
10. Transportation machinery	3.28	2.95	0.33	10.28
11. Wooden products and furniture	2.32	2.19	0.12	5.57
12. Pulp and paper products	4.35	3.97	0.37	8.67
13. Rubber products	3.69	2.97	0.71	19.46
14. Leather and leather products	2.64	2.43	0.21	8.03
15. Chemical products	3.19	2.66	0.52	16.52
16. Fiber and fabrics	2.36	2.14	0.21	9.15
17. Apparel and shoes	2.60	2.42	0.18	7.11
18. Food	2.90	2.72	0.17	6.06
19. Beverage and tobacco	2.39	2.23	0.16	6.70
20. Printing and publishing	2.53	2.15	0.38	15.05
21. Other manufacture	2.72	2.43	0.28	10.65
22. Electricity	1.19	1.15	0.03	3.18
23. Water services	3.59	3.36	0.22	6.39
24. Civil engineering	2.23	2.06	0.16	7.57
25. Commerce	1.23	1.21	0.02	2.11
26. Transportation	3.66	3.09	0.56	15.48
27. Communication	1.18	1.15	0.03	2.75
28. Finance	1.14	1.13	0.01	1.00
29. Other services	1.41	1.38	0.03	2.69
30. Unclassifiable	32.24	29.80	2.43	7.56
31. Total	108.94	98.91	10.03	9.21

nological improvements that lower the relative amount of coking coal required in production.

One can get an idea of the extent to which production activity on the part of USIMINAS stimulates production in the various industrial sectors of the Brazilian economy by calculating the backward linkage matrix. The results of such calculation, given in Table VI, show that when final demand for USIMINAS products (F^{d}_{5}) occurs, the company's production activity is induced and that this has a repercussion effect on the entire Brazilian economy through the company's procurements of raw materials and services ($B^{d}_{j5} F^{d}_{5}$).

TABLE
BACKWARD LINKAGE

	Agriculture 1	Mining 2	Ceramics 3	Iron and steel except USIMINAS 4	USIMINAS 5	Non-ferrous metal 6	Metal processing 7	Industrial machinery 8	Electric and electronics machinery 9	Transportation machinery 10	Wooden products and furniture 11
1. Agriculture	328	5	4	35				1			48
2. Mining	2	83	20	24	2365	16	1	1	1		
3. Ceramics		6	26	2	22		2	2	11	5	2
4. Iron & steel except USIMINAS		1	4	487		23	211	123	30	34	4
5. USIMINAS			1		62712		53	4	6	16	
6. Non-ferrous metal				9	20	117	70	18	51	9	1
7. Metal processing		3	2	7	668		97	40	18	27	10
8. Industrial machinery	7	4		1	86			90	8	15	
9. Electric and electronics machinery				3	323		1	27	115	18	
10. Transportation machinery								11		116	
11. Wooden products and furniture		4	1	1	101		4	9	7	2	39
12. Pulp and paper products			8		10	1	4	1	3		
13. Rubber products	4	1			10		1	9	1	20	3
14. Leather and leather products											
15. Chemical products	161	121	30	58	20309	17	45	25	34	17	17
16. Fiber and fabrics	11		1					1		1	5
17. Apparel and shoes										2	
18. Food	44				13						
19. Beverage and tobacco											
20. Printing and publishing							3				
21. Other manufacture		212	14	71	3243	10	34	33	16	17	6
22. Electricity	6	82	11	27	2389	21	15	9	6	4	4
23. Water services											
24. Civil engineering											
25. Commerce	29	79	30	76	11738	53	69	41	42	17	17
26. Transportation	4	31	5	2	5356	7	1	1			2
27. Communication											
28. Finance											
29. Other services											
30. Unclassifiable	28	43	9	27	333	9	19	35	25	13	2
31. Total	625	673	164	829	109699	277	631	479	376	335	161

VI
MATRIX FOR USIMINAS

(Cr$ 1,000)

Pulp and paper products 12	Rubber products 13	Leather and leather products 14	Chemical products 15	Fiber and fabrics 16	Apparel and shoes 17	Food 18	Beverage and tobacco 19	Printing and publishing 20	Other manufacture 21	Electricity 22	Water services 23	Civil engineering 24	Commerce 25	Transportation 26	Communication 27	Finance 28	Other services 29	Unclassifiable 30	Total 31
42	27	1	1411	75		505	7		68			3		1			65		2626
3			1043			2			32			3		2					3598
3			166			2	1		15			39	15	2			3	136	461
1	1		4					12	59			16		6			3	339	1359
																			62792
5			35					13	186					4					541
1	3		134			15	1	4	67			17	112	34			11	106	1376
									3			2	5				10	1017	1246
			1						38	81		8	16	32	21		46	247	975
									1				73	389	4		65		660
14			23			1		1	65			14	39	3			7		335
443			245	3		10	1	442	98			1	173			73	7	380	1905
	55		15	1					12				112	121			7	233	606
		2	2		1			1	24						2		11		43
107	91	5	3307	81		49	2	92	415	95		16	230	459	7	2	150	409	26352
6	18		354	136	2	14		5	103				38				42		739
														3			1		6
8		12	527	1		207	2		20				15	8			447		1306
			1				3						5	9			39		58
5			20					166	8				32	1		352	40	2910	3540
75	6	1	463	22		16	1	56	174	15		2			4	16	129	192	4827
54	7		244	10		10		22	67	59		1	94		10	56	113	570	3892
																	3		3
														331					331
96	25	2	1193	45		76	2	159	220	15		33	406	119	9	94	410	1056	16150
4			217	1		5		2	14	5		2		144	56	1	1	950	6811
														5		40	6	1849	1901
																		18442	18442
												1	229	420	2	849	304	8528	10333
103	21		774	2		13	1	42	97					316			2	281	2197
973	257	24	10179	378	3	923	23	1018	1787	271	1	157	1595	2408	115	1483	1921	37646	175412

TABLE
POWER OF LINKAGE DISPERSION

	Agriculture 1	Mining 2	Ceramics 3	Iron and steel except USIMINAS 4	USIMINAS 5	Non-ferrous metal 6	Metal processing 7	Industrial machinery 8	Electric and electronics machinery 9	Transportation machinery 10	Wooden products and furniture 11
1. Agriculture											
2. Mining	71	7	32	8	2365		2667	815	833	7058	145
3. Ceramics	1				22		25	8	8	65	1
4. Iron & steel except USIMINAS											
5. USIMINAS	1880	192	861	221	62712	6	70724	21602	22100	187150	3838
6. Non-ferrous metal	1				20		23	7	7	61	1
7. Metal processing	20	2	9	2	668		754	230	235	1994	41
8. Industrial machinery	3		1		86		97	30	30	256	5
9. Electric and electronics machinery	10	1	4	1	323		364	111.	114	964	20
10. Transportation machinery											
11. Wooden products and furniture	3		1		101		114	35	36	302	6
12. Pulp and paper products					10		11	3	3	29	1
13. Rubber products					10		12	4	4	31	1
14. Leather and leather products											
15. Chemical products	609	62	279	72	20309	2	22904	6996	7157	60608	1243
16. Fiber and fabrics											
17. Apparel and shoes											
18. Food					13		15	5	5	40	1
19. Beverage and tobacco											
20. Printing and publishing											
21. Other manufacture	97	10	45	11	3243		3658	1117	1143	9679	199
22. Electricity	72	7	33	8	2389		2694	823	842	7129	146
23. Water services											
24. Civil engineering											
25. Commerce	352	36	161	41	11738	1	13238	4043	4137	35030	718
26. Transportation	161	16	74	19	5356	1	6041	1845	1888	15985	328
27. Communication											
28. Finance											
29. Other services											
30. Unclassifiable	10	1	5	1	333		376	115	117	994	20
31. Total	3288	335	1507	386	109699	11	123715	37787	38658	327375	6714

VII
MATRIX FOR USIMINAS

(Cr$ 1,000)

	Pulp and paper products 12	Rubber products 13	Leather and leather products 14	Chemical products 15	Fiber and fabrics 16	Apparel and shoes 17	Food 18	Beverage and tobacco 19	Printing and publishing 20	Other manufacture 21	Electricity 22	Water services 23	Civil engineering 24	Commerce 25	Transportation 26	Communication 27	Finance 28	Other services 29	Unclassifiable 30	Total 31
	12	18	9	209	56	81	736	85	15	93	13	14	3479	484	637	5		131	78	20157
				2	1	1	7	1		1			32	4	6			1	1	186
	309	476	246	5547	1482	2141	19504	2267	407	2457	339	376	92254	12845	16878	133		3474	2073	534494
				2		1	6	1		1			30	4	5			1	1	173
	3	5	3	59	16	23	208	24	4	26	4	4	983	137	180	1		37	22	5695
		1		8	2	3	27	3	1	3		1	126	18	23			5	3	731
	2	2	1	29	8	11	100	12	2	13	2	2	475	66	87	1		18	11	2752
		1		9	2	3	32	4	1	4	1	1	149	21	27			6	3	864
				1			3						15	2	3			1		84
				1			3						15	2	3			1		88
	100	154	80	1796	480	693	6316	734	132	796	110	122	29876	4160	5446	43		1125	671	173095
				1			4			1			20	3	4			1		115
	16	25	13	287	77	111	1009	117	21	127	18	19	4771	664	873	7		180	107	27644
	12	18	9	211	56	82	743	86	16	94	13	14	3514	489	643	5		132	79	20360
	58	89	46	1038	277	401	3651	424	76	460	63	70	17268	2404	3159	25		650	388	100044
	26	41	21	474	127	183	1666	194	35	210	29	32	7880	1097	1442	11		297	177	45652
	2	3	1	29	8	11	104	12	2	13	2	2	490	68	90	1		18	11	2840
	541	832	430	9703	2593	3744	34118	3965	713	4298	592	657	161378	22470	29525	233		6078	3626	934973

Furthermore, one can get an idea of how widely the company's overall production and product shipment activties affect the Brazilian economy by calculating the power of linkage dispersion matrix. Table VII gives the results of such calculation. Each figure in the table shows induced production, by consumers of USIMINAS products, of raw materials used in USIMINAS' production activities ($X^d_{i5k} = A^d_{i5}\ B^d_{5k}\ F^d_k$). In other words, each increment in final demand $k\,(F^d_k)$ induces direct and indirect increments of intermediate demand for USIMINAS products (B^d_{5k}), which in turn induce demand for raw materials of i (A^d_{i5}).

Table VII shows that a considerable portion of production by USIMINAS is used by the transportation machinery (column 10), civil engineering (column 24), metal processing (column 7), and other sectors as their input materials and that the use of raw materials by USIMINAS induces production mainly of pig iron and crude steel by USIMINAS itself (row 5), chemical products (coking coal, row 15), commercial services (row 25), transportation services (row 26), other manufactured products (row 21), mining products (row 2), electricity (row 22), etc.

In the ten years since then Brazil's industrial structure has undergone further import substitution of capital and intermediate goods for increased consumption of USIMINAS flat steel products (Table III). The input structure of steel production by USIMINAS has seen change in the direction of economization of raw materials on the basis of technological progress, and the company's share of the total production of the Brazilian iron and steel industry has increased from 15.8 per cent (850,000 tons a year) to 21.3 per cent (3,260,000 tons a year). Accordingly, it is surmised that since 1980 the backward linkage effect has further increased, leaks to other countries declining and the positive repercussions on the Brazilian economy spreading further.

B. *Construction and Expansion of Integrated Steel Plants*

Construction and expansion of integrated steel plants has also contributed to the development of the Brazilian economy through procurement of construction materials and machinery and equipment. For USIMINAS' initial plant construction and its first two phases of expansion imports were relied upon for approximately 80 per cent of the machinery and equipment. Although at the time of implementation of USIMINAS' second phase expansion the Brazilian government gave preferential treatment aimed at raising the percentage of machinery and equipment of domestic origin and deviated from the principle of international tenders as the means of procurement of machinery and equipment in the case of some items that Brazilian enterprises seemed capable of supplying, the percentage of the total represented by domestically manufactured machinery and equipment in the procurement rose to only about 22 per cent [10, p. 38]. In the third phase of expansion (1977–82), however, at the point of conclusion of purchase contracts for 170 packages of the total of 183 packages, 70 per cent of the total contract value (i.e., U.S.$474 million) was accounted for by domestic procurement [10, p. 41].

Such improvement of the percentage of procurement represented by domestically manufactured machinery and equipment has been made possible by cooperation between the USIMINAS, the purchaser, and the manufacturers. At the beginning of the third phase expansion USIMINAS surveyed the processing equipment, technological descent and technological level of the various domestic machinery manufacturers and subdivided all of the machinery and equipment package in line with the capabilities of such manufacturers in order to make it possible to place orders with them [10, pp. 38–9]. Internally it also reorganized the engineering division so as to make possible technical adjustment of domestically manufactured machinery and equipment. Furthermore, it encouraged domestic manufacturers to modernize their plants and equipment, introduce foreign technology, and form consortiums. That is how the figure of 70 per cent has been attained for the percentage of procurement of machinery and equipment represented by domestic manufacturing in the third phase of expansion.

V. CONCLUSION

USIMINAS has contributed to the development of the Brazilian automobile, shipbuilding, and other industries by providing them with good-quality flat steel products at low price for use by them as input materials. As an investment project, it can be considered a success. Five main factors can be cited for the fact that it has succeeded.

First of all, there is the fact that demand for flat steel products substantially increased as a result of Brazil's policy of heavy industrialization. Along with such increase in demand, USIMINAS invested in expansion of its facilities, which resulted in streamlining of the production system, improvement of technology, introduction of new technology, and rise of productivity.

Secondly, there is the fact that Brazil is richly endowed with quality iron ore. As we have seen, it is dependent on imports of coking coal from the United States which are costly because of the long distance involved in transporting it, but thanks to the low price of iron ore the overall cost of raw materials per ton of production of flat steel products is not higher than the internationally prevailing level. Furthermore, relative lowering of the quantities of coking coal, and fuel used in production through introduction of new technology has also contributed to the holding down of the cost of raw materials.

The third factor in USIMINAS' success story is the fact that the company has striven to make as much use as possible of domestically produced raw materials and machinery and equipment, making for a greater effect of economizing on foreign exchange. Besides contributing to holding down imports of coking coal and petroleum products by lowering the coke rate and fuel rate in its production, it has also done its utmost to economize on foreign exchange by raising the percentage of procurement of domestically manufactured machinery and equipment in expanding its plant facilities. As a result, USIMINAS has economized on foreign exchange through import substitution of flat steel products in fifteen of the twenty-one years that it has been in operation.[5]

[5] The effect of net foreign exchange savings is estimated by deducing foreign exchange expense (importation of coal, opportunity cost of other raw materials foregoing incurred

The fourth factor is the fact that although USIMINAS does not provide all that much direct employment, its indirect employment effect on related industries has been considerable. USIMINAS employs only 6,800 persons (1970) directly, but thanks to its products it has created jobs for 16,300 persons in such labor-intensive industries as shipbuilding and the automobile industry.[6] Furthermore, it has created 20,600 jobs in such labor-intensive industries as mining, commerce, and transportation through procurement of raw materials and services.

The fifth and final factor in the success of USIMINAS as an investment project is the fact that it was started as joint venture with Japan, which was responsible for construction and operation of the initial 500,000-ton plant from the basic design to operation assistance. From the very outset of operation of the plant production performance was good, and within five years the production goal of 500,000 tons was achieved without any major investment in additional equipment. By the tenth year of operation production was more than doubled to 1,180,000 tons, mainly through modification of incidental equipment and improvement of technology.

Such smooth expansion of production contrasts sharply with the performance of another integrated iron and steel manufacturing plant that got started at the same time, the Paulista Steel Co. (Companhia Siderúrgica Paulista), for which the U.S. firm Kaiser Steel Corporation undertook the basic design work, construction, and assistance in operation. Its initial goal was a production scale of 2 million tons, but there were major delays in its construction, and it was only able to produce 600,000 tons owing to the small pig iron production capacity of its blast furnaces. It took until later than 1975 to achieve the 1-million-ton production mark, and then only after expansion of production facilities. In 1980 it finally reached the 3-million-ton mark.

One can draw the conclusion that with Japan as a participant in the investment with an interest in achieving an acceptable operational profit, it was easier to arrange technology transfer and establish efficient operation of the plant, which resulted in higher productivity.

From this analysis of the factors of the success of the USIMINAS project it would appear to be desirable that investment projects in developing countries be implemented in fields where one can expect considerable increase in domestic demand, a major effect of economizing on foreign exchange, mainly because of the possibility of use of domestically exploited resources and domestically manufactured equipment, and a substantial direct and indirect employment effect. One can also conclude that the most effective arrangement for implementation of such projects is joint ventures with foreign firms that can furnish advanced technology.

in operation, debt repayments and interest on debt), from the gross savings in foreign currency that is derived from steel production (the c.i.f. price at a Brazilian port = gross sales value in f.o.b. Europe plus freight charge) [8, p. 23] [9, p. 25].

6 The number of workers needed to make products worth a million cruzeiros (the labor coefficient) is 5.7 for USIMINAS, 34 for mining, 26.6 for electricity, 57.9 for commerce, 69.0 for transportation, 28.7 for metal processing, 16.2 for transportation equipment, and 63.0 for civil engineering.

REFERENCES

1. *Banco central do Brasil boletim mensal,* Vol. 17, No. 10 (October 1981).
2. Bank of Japan. *Shuyō kigyō keiei bunseki, Shōwa 58 nendo* [Financial statement of principal enterprises, 1983] (Tokyo, 1984).
3. Committee on Economic Studies. *Projection 85: World Steel Demand* (Brussels: International Iron and Steel Institute, 1972).
4. "Contas nacionais e parâmetros da economia brasileira," *Conjuntura econômica,* Vol. 35, No. 2 (February 1981).
5. CORDEN, W. M. *Trade Policy and Economic Welfare* (Oxford: Clarendon Press, 1974).
6. CRANDALL, R. W. *The U.S. Steel Industry in Recurrent Crisis: Policy Options in a Competitive World* (Washington, D.C.: Brookings Institution, 1981).
7. Instituto Brasileiro de Siderurgia. *Anuário estatístico da indústria siderúrgica brasileira* [Statistical yearbook of Brazilian steel industry] (Rio de Janeiro: Instituto Brasileiro de Siderurgia, 1982).
8. International Bank for Reconstruction and Development. "Brazilian Steel Expansion Program, Part II. Appraisal on Usiminas Expansion Project," mimeographed (Washington, D.C., 1972).
9. ————. "Project Performance Audit Report, Brazil—USIMINAS Stage II Expansion Project," mimeographed (Washington, D.C., 1979).
10. KASHIBUCHI, T. "Uziminasu-sha ga burajiru kōgyō ni oyoboshita eikyō" [The effects of USIMINAS steel production on Brazilian industrial development], typescript (1982).
11. ————. "Uziminasu-sha no tōnyū-sanshutsu kōzō no suitei, 1970 nen" [Estimation on input-output structure of USIMINAS, 1970, typescript (1982).
12. "Notícias da ANFAVEA" [Notices of ANFAVEA], No. 324 (São Paulo: Associação Nacional dos Fabricantes de Veículos Automotores, 1982).
13. Secretaria de Planejamento da Presidência da República, Instituto Brasileiro de Geografia e Estatistica. *Matriz de relações intersetoriais Brasil 1970 (Versão final)* [Brazilian intersectoral relation matrix 1970 (Final version)] (Rio de Janeiro, 1979).
14. Tekkō Tōkei Iinkai (Committee of iron and steel statistics). *Tekkō tōkei yōran* [Statistical handbook of the iron and steel] (Tokyo: Tekkō Tōkei Iinkai).
15. TODA, H. *Gendai sekai tekkōgyō ron* [Theory on modern world steel] (Tokyo: Bunshindō, 1984).
16. TORII, Y. "An Analysis of a Newly Established Iron and Steel Industry in West Malaysia," in *Input-Output Models, Theory, Data and Application,* ed. Institute of Developing Economies, IDE Statistical Data Series No. 47 (Tokyo: Institute of Developing Economies, 1985).
17. TORII, Y., and FUKASAKU, K. "Economic Development and Changes in Linkage Structure: An Input-Output Analysis of the Republic of Korea and Japan," in *Proceedings of the Seventh International Conference on Input-Output Techniques,* ed. United Nations Industrial Development Organization (New York: UNIDO, 1984).
18. United Nations. *Demographic Yearbook, 1980* (New York, 1982).
19. United Nations University Project on Technology Transfer, Transformation and Development: The Japanese Experience. "Technology Transfer from Japan to Brazil in the Iron and Steel Industry: The Case of USIMINAS, Final Version," Report submitted to United States University, typescript (1982).
20. Usinas Siderúrgicas de Minas Gerais, S.A. *Relatório anual* [Annual report] (Belo Horizonte).
21. ————. *Relatório da administração 1981* [Report of administration 1981] (Belo Horizonte, 1982).

APPENDIX

CALCULATING THE LINKAGE EFFECTS OF USIMINAS ON ECONOMIC DEVELOPMENT

To analyze the effect that USIMINAS has on economic development, I used a linkage structure model that was developed by Professor Yasuhiko Torii and which he has applied to calculations of the linkage effect of Malayawata Steel Berhad [16] [17]. The following sections briefly describe this model as well as other indices and data that I used in my analysis.

A. *Model and Indices*

1. *Forward and backward linkage effects*

I calculated two kinds of inverse matrix based on the input-output tables. One is the domestic inverse matrix (B^d_{ij}) the other is the total inverse matrix (B^c_{ij}).

The domestic inverse matrix is defined as,

$$B^d = (I - A^d)^{-1}, \qquad (1)$$

where A^d is an input coefficient matrix, the calculations of which are based on a domestic transaction table, and B^d is an inverse coefficient matrix. The inverse matrix of the total transaction table, domestic and imported products, is calculated as,

$$B^c = (I - A^c)^{-1} = [I - (A^d + m)]^{-1}, \qquad (2)$$

where B^c denotes an inverse matrix of the total transaction table, A^c is an input coefficient matrix of the total transaction and m is an import input coefficient matrix.

The row sum of B^c is the "total forward linkage effects" (Table I) of industry i, ${}^{LE}FT_{,i}$, which indicates the forward linkage inducement effects of domestic and imported supplies.

$${}^{LE}FT_{,i} = \sum_{j=1}^{n} B^c_{ij}. \qquad (3)$$

The column sum of B_c is the "total backward linkage effect" (Table V) of industry j, ${}^{LE}BT_{,j}$. This implies the backward linkage inducement effect of domestic and imported demand,

$${}^{LE}BT_{,j} = \sum_{i=1}^{n} B^c_{ij}. \qquad (4)$$

Similarly, the row sum of B^d is the "domestic forward linkage effect" of industry i, ${}^{LE}FD_{,i}$. This gives the forward linkage inducement effect of domestic supplies from industry i to other industries,

$$ {}^{LE}FD_{,i}=\sum_{j=1}^{n} B_{ij}^{d}. \tag{5}$$

The column sum of B^d is the "domestic backward linkage effect" of industry j, ${}^{LE}BD_{,j}$. This provides the backward linkage inducement effect of domestic demand,

$$ {}^{LE}BD_{,j}=\sum_{i=1}^{n} B_{ij}^{d}. \tag{6}$$

2. *Leak in linkage effect*

The forward and backward linkage effects induced in every industry may leak to foreign industry in the form of import demand. The leak of forward linkage effect of industry i, ${}^{LK}F_{,i}$, is found by subtracting domestic forward linkage effect from total forward linkage effect:

$$ {}^{LK}F_{,i}={}^{LE}FT_{,i}-{}^{LE}FD_{,i}=\sum_{j=1}^{n} B_{ij}^{c}-\sum_{j=1}^{n} B_{ij}^{d}. \tag{7}$$

Similarly, leak of backward linkage effect of industry j, ${}^{LK}B_{,j}$, is derived by

$$ {}^{LK}B_{,j}={}^{LE}BT_{,j}-{}^{LE}BD_{,j}=\sum_{i=1}^{n} B_{ij}^{c}-\sum_{i=1}^{n} B_{ij}^{d}. \tag{8}$$

3. *Linkage structure model*

More detailed information on how the linkage effect is diffused within industry can be derived from a linkage structure model. In a model of this type, the diffused linkage effect has three dimensions, X_{ijk}, that is, final demand k ($k=1, \cdots, n$) induces intermediate demand j ($j=1, \cdots$, n), and, thereby, there is a demand for input i ($i=1, \cdots, n$) to produce each intermediate product j.

This model is therefore written in the form of Kronecker's product for each "element of linkage," X_{ijk}, as:

$$X_{ijk}=A_{ij}\otimes B_{jk}\otimes F_{k}.$$

Where X_{ijk} stands for the element (i, j, k) of the three-dimensioned matrix that indicates the production of the ith product that is ultimately induced. F_k stands for the kth element of the final demand diagonal matrix, B_{jk} for the (j, k)th element of the inverse matrix, and A_{ij} for the (i, j)th element of the input coefficient matrix. In other words, the increment in final demand $k(F_k)$ induces direct and indirect increments of intermediate demand of $j(B_{jk})$, and B_j, induces final input demand for the ith product (A_{ij}).

(1) Forward linkage matrix

As equation (10) demonstrates, the $(j\times k)$ forward linkage matrix $X_{\bar{i}jk}$ fixes the ith row vector of A_{ij}. This shows the amount of industry i's input product that is necessary for each industry j to increase its production which is induced by the final demand of each k industry. In other words, it gives a decomposition of the forward linkage effects of $\bar{i}$ industry generated by each final demand.

$$X_{\bar{i}jk}=A_{\bar{i}j}\,B_{jk}\,F_k \qquad (10)$$

$$=\left[\begin{pmatrix} a_{\bar{i}1}\cdots\cdots & 0 \\ \vdots & \vdots \\ 0\ \cdots\cdots & a_{\bar{i}n} \end{pmatrix}\begin{pmatrix} b_{11}\ b_{12}\cdots\cdots & b_{1n} \\ \vdots & \vdots \\ b_{n1}\ \cdots\cdots\cdots & b_{nn} \end{pmatrix}\begin{pmatrix} f_1\cdots\cdots & 0 \\ \vdots & \vdots \\ 0\ \cdots\cdots & f_n \end{pmatrix}\right]^T$$

Therefore if product $\bar{i}$ is steel made by USIMINAS, the forward linkage matrix shows the intermediate demand for USIMINAS product as induced by the final demand from each industry (Table II).

(2) Backward linkage matrix

The $(i\times j)$ backward linkage matrix fixes the kth column of the inverse matrix and gives the production of industry i in meeting intermediate demand for industry j that is induced by the final demand for the kth product. In other words, it gives a detailed picture of the backward linkage effects of industry $\bar{k}$ when $f_{\bar{k}}$ is the scaler in equation (11) below.

$$X_{ij\bar{k}}=A_{ij}\,B_{jk}\,F_{\bar{k}} \qquad (11)$$

$$=\begin{bmatrix} a_{11}\ a_{12}\cdots\cdots & a_{1n} \\ a_{21} & \vdots \\ \vdots & \vdots \\ a_{n1}\ \cdots\cdots\cdots & a_{nn} \end{bmatrix}\begin{bmatrix} b_{1\bar{k}}\cdots\cdots & 0 \\ \vdots & \vdots \\ 0\ \cdots\cdots & b_{n\bar{k}} \end{bmatrix} f_{\bar{k}}$$

Therefore, if industry $\bar{k}$ is taken to be USIMINAS, the backward linkage matrix of USIMINAS implies the inducement of production activities for various industries that supply input material to USIMINAS (Table VI).

(3) Power of linkage dispersion matrix

The $(i\times k)$ power of linkage dispersion matrix $X_{i\bar{j}k}$ with the jth row of B_{jk} and the jth column of A_{ij} given, shows the production for all i industries which is induced by j $(j=\bar{j})$'s intermediate demand. In other words, a picture of the power of linkage dispersion in industry j is presented as:

$$X_{i\bar{j}k}=A_{i\bar{j}}\,B_{\bar{j}k}\,F_k \qquad (12)$$

$$=\begin{bmatrix} a_{1\bar{j}} \\ a_{2\bar{j}} \\ \vdots \\ a_{n\bar{j}} \end{bmatrix}[b_{\bar{j}1}\ b_{\bar{j}2}\cdots\cdots\cdots\cdots b_{\bar{j}n}]\begin{bmatrix} f_1\cdots\cdots & 0 \\ \vdots & \vdots \\ 0\ \cdots\cdots & f_n \end{bmatrix}$$

Therefore, if industry $\bar{j}$ is taken to be USIMINAS, power of linkage dispersion matrix indicates the necessary input materials of each industry to feed a needed supply of USIMINAS products in meeting the final demand from each industry (Table VII).

B. *Data*

The basic data used to calculate the economic development linkage effects of USIMINAS is taken from *Matriz de relações intersetoriais Brasil 1970* (*Versão* *final*) [13]. This data was adjusted for our purposes by taking data on the input and output structure of USIMINAS from Kashibuchi [11] and putting it into the above Brazilian input-output table.

The three input-output tables of Brazil are: one for 1959, which was compiled by the Instituto de Planejamento Economico e Social (32 by 32 endogenous sectors); and one for 1970 (158 by 87 endogenous sectors) and 1975 that were compiled by the Instituto Brasileiro de Geografia e Estatistica. The second and third input-output tables are based on the United Nations' *A System of National Account*.[a] Matrix V (industries by commodities), Matrix U (commodities by industries), and an import matrix (commodities by industries) were compiled for 86 industries and 158 commodities.

[a] Studies in Method Series F, No. 2, Rev. 3 (New York, 1968).