1984

The Potential Impact And Optimal Adjustment Associated With An Aluminum Supply Restriction: A Case Study Of Taiwan

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West Virginia University PH.D. 1984

University
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THE POTENTIAL IMPACT AND OPTIMAL ADJUSTMENT ASSOCIATED WITH AN ALUMINUM SUPPLY RESTRICTION: A CASE STUDY OF TAIWAN

DISSERTATION

Submitted to the

College of Mineral and Energy Resources

of

West Virginia University

In Partial Fulfillment of the Requirements for

The Degree of Doctor of Philosophy

by

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Morgantown

West Virginia

1984

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to a number of individuals for their valuable assistance throughout my study. Long-standing thanks are due to Professor Adam Rose, chairman of the committee, who has most graciously shared his insights with me. I am also indebted to Professors Walter C. Labys, Thomas F. Torries, Tom S. Witt, and Ming-Jeng Hwang for their useful comments and suggestions for improving the research.

I am most grateful to Professor Dorothy Sedley, of the Department of English, and my colleague Gregg Davis for their help in editing, and to Nancy Ireland, who typed the dissertation. My brother, C. R. Chen must also be sincerely thanked for supplying me with various types of data necessary to complete my research.

Finally, innumerable thanks are due to my wife, Ming-Jyue, and my parents for their sharing with me the joy and hardship throughout my study.

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CHAPTER I

INTRODUCTION

A. BACKGROUND

Since the Arab oil embargo in 1973-1974 and subsequent dramatic OPEC price increases, concern has been growing over the impact of critical mineral supply restrictions on the economies of the mineral importing nations. The causes for this concern are varied, but there is enough evidence to indicate a substantial risk in counting on secure supplies and low prices of critical minerals in the future (Tilton, 1977). Although exhaustion of many mineral resources is unlikely in the near future, a short-term supply restriction leading to a rapid price increase and general inflationary pressures can impose a significant negative impact on the economy and security of a nation. The domination of critical mineral markets by a small number of producers increases the possibility of market manipulation and supply disruption. In the past decade, international raw material trade has been subject to important changes and politics has intruded into this trade (Radetzki, 1978). As long as the world political and economic situation is continually unstable, one cannot ignore the possibility of a supply restriction. This study responds to the need for quantitative analysis of the consequences of supply restrictions on an economy and of the optimal economic adjustment policy.

Taiwan, one of the more rapidly developing countries, has limited metallic mineral resources. Almost all the sizeable demand of metallic minerals depends on imports and thus the Taiwan economy is highly vulnerable to metallic mineral supply restrictions. The high dependency of metallic mineral supply on imports, together with the possibility of a politically motivated supply restriction and the lack of political leverage, make it reasonable to assume that the country faces the possibility of a metallic mineral supply restriction in the short-term. Therefore, constructing a framework to analyze this problem is very important to Taiwan.

The purpose of this study is to formulate a model to evaluate the short-term economic impacts of a supply restriction and to devise alternative adjustment policies that will minimize the economic costs of the event. The application of the model is restricted to aluminum.* However, the analytical framework developed in this study can also be applied to any other critical mineral commodity.

B. LITERATURE REVIEW

In this section, early analytical approaches used to determine the impact of a supply restriction are reviewed and compared with the analytical approach presented in this study.

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*There are three justifications for selecting aluminum as the case study. First, the potential percentage increase in profit from a supply restriction for the exporting countries is greater for bauxite than for oil (Pindyck, 1977). Second, according to an interdepartmental study by the U.S. Department of the Interior (Enzer, 1978), aluminum/bauxite, chromium, and the platinum metals have the greatest potential for supply restrictions globally in the near future. Lastly, data available precludes any detailed analysis for metallic minerals other than aluminum.

In general, two analytical methods have been primarily used in impact analysis. They are consumers' surplus analysis and input-output (I-O) analysis. One of the early studies based on consumer surplus analysis was conducted by the Office of Minerals Policy Development, U.S. Department of the Interior (1975), in which the impacts of a restriction in aluminum, chromium, platinum, and palladium were analyzed. Basically, the analytical framework employed is first to build up the domestic supply and demand models and then derive the amount of imports. According to the assumption about the availability of imports, the price induced response from domestic demand and supply can be analyzed. The welfare loss in the whole economy is calculated by the total consumers' surplus loss minus the total domestic producers' surplus increase. In 1976, Charles River Associates (CRA) constructed a formal framework for the U.S. National Bureau of Standards to analyze the impact of a supply restriction. This framework is also based on the consumers' surplus concept. The advantage of this type of analysis is that it can properly reflect the price and income effects on the demand for the commodity in question. But its disadvantage is it only yields aggregative measure of the impact. Consumers' surplus analysis is unable to identify the impact on each sector in the economy and to determine second-order impacts on the whole economy. Another problem is that the accuracy of the analytical results will significantly depend on the accuracy of the estimation of the price and income elasticities.

Impact analysis based on the I-O model is exemplified by the work of the U.S. Bureau of Mines (1981). This report concluded that there is a very low possibility of a total cutoff in chromium imports for the U.S., but there is a potential for severe, repetitive disruptions. The average loss in gross national product (GNP) from the average disruption would be $1.0 billion during the 1982-1990 period, but it would jump to $9.3 billion for a total cutoff in imports for the five year period. However, the economic loss could be reduced from 9-17 percent by government policies, such as stockpiling and price supports.

Unfortunately, this report was vague on the nature of the I-O model used to analyze the impact. Generally, there are two I-O approaches that can be employed to analyze the impact of a commodity supply restriction. One is the conventional I-O model in which the input coefficient is given, but the allocation coefficient is allowed to change freely.* Because the allocation function would play a very important role during a supply restriction, the major problem of this model is therefore how to calculate the allocation coefficient for each sector. This is beyond the ability of the conventional I-O model itself. The second is the "supply-driven" model, in which the allocation coefficient is given, but the input coefficient is allowed to change freely as first demonstrated by Ghosh (1958). Hoover (1975) indicated that the "supply-driven" model may be more appropriate to deal with the impact from primary supply or forward linkage because the model

*The input coefficient is defined as the proportion of total outlays being spent in each of the productive sectors. The allocation coefficient is defined as the proportion of total output being sold to each of the productive sectors. Input-output analysis will be discussed in detail in Chapter 5.

basically takes demand for granted and thus makes sector activities depend on the availability of primary inputs. Giarratani (1976) applied this model to the availability of energy inputs with the use of the supply multiplier.*

Conceptually, the potential problem of the "supply-driven" model is that the substitution among inputs (i.e., changes in input coefficients) implicit in its solution may be unreasonable. This problem will be tested in Chapter V in the context of the Taiwan 1979 I-O table. However, neither a conventional I-O model nor a "supply-driven" model can operate the production function and the allocation function simultaneously. Besides, subject to the assumption of fixed input coefficients or fixed allocation coefficients, the impact of each unit change in commodity supply is also fixed. This will overestimate the analytical result in the case of a mild supply restriction and underestimate the result in the case of a severe supply restriction. The only advantage of simple I-O analysis is to be able to identify the impact on each sector and calculate the total impact (including hidden or second-order effects) on the whole economy.

The most recent study about the vulnerability to a commodity supply restriction was done by Hazilla and Kopp (1983). They utilize a two stage neoclassical econometric model to first estimate the inter-commodity substitution possibility and then to analyze the intra-factor (labor, energy, material, and capital) substitution

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*The supply multiplier is defined as the change in total gross output due to a unit change in a primary input.

possibility. Based on the estimation result, the value of lost output and the cost of forced substitution due to a commodity supply restriction can be calculated. The study's empirical findings highlighted the extreme discontinuity of supply disruption impacts. This is because the potential of substitution is relatively unrestricted during a less than 50 percent supply disruption. Beyond that, substitution possibilities among inputs quickly approach exhaustion. The economic loss substantially increases because the cost of a forced reduction in output due to low substitution possibilities comes together with the cost of forced substitution.

This study differs from I-O analysis in that the model is able to identify substitution possibilities, output loss due to the material constraint, and the cost of forced substitution. However, it is only a partial equilibrium analysis rather than a general equilibrium analysis capable of estimating indirect impacts.

There are important departures here from the previous studies of the impact of a commodity supply restriction. First, the model presented here makes use of the linear programming (LP) framework to generalize I-O analysis in order to simultanously handle the production function and the allocation function. Second, substitution among related commodities estimated by the translog production function is incorporated into this activity analysis in order to include a part of the price induced effect. Third, the model presented here not only is able to identify the impact of a commodity supply restriction on each sector, but also is able to present the optimal and practical adjustment pattern. This is of great importance to policy-makers, because the assessment of the sensitivity of each sector to a supply restriction and the formulation of practical adjustments are among their major concerns.

C. ANALYTICAL APPROACH

The approach of this study is to use an I-0 model together with the LP technique to analyze the impact of restricted aluminum supplies on the economy of Taiwan and to derive the optimal adjustment pattern of the output structure in the economy. The major methodological contributions of this study will be to advance the state-of-the-art of I-0 modeling by incorporating substitution effects into the optimal solution and to formulate the optimal adjustment policies to alleviate the adverse impact of a supply restriction. Another contribution is to derive the optimal allocation criteria (coefficients) from the solution of an LP model. The resulting model is used to predict the impact of a supply restriction, indicate each sector's optimal response for mitigating the impact, and present the optimal allocation function to policy makers.

In order to incorporate the substitution effect into the LP model, the price change during a supply restriction has to be estimated first. For this reason, an econometric demand model for the domestic aluminum industry will be set up in the first stage in this study. The relationship between the aluminum sector and other sectors is described in terms of the forward and backward linkages of the economy.

The second stage of this study is to estimate the possibility of substitution between aluminum and copper commodity inputs in Taiwan.

The analytical approach is based on a two-stage translog production function. From the estimated result, the net substitution effect can be obtained and will be incorporated into I-O model to change the input coefficients.

The third stage of the study will analyze the impact of a supply restriction based on both a consumers' surplus analysis and an I-O analysis. The "supply-driven" approach to I-O analysis will be used. The impact of the substitution effect on the analytical results is also investigated in this stage. However, technological change during supply restrictions is ignored in the case study for aluminum. The reasons for this are: 1) although aluminum consumption and its new uses grow rapidly, aluminum technology has changed little in the last few decades; 2) there are some new techniques of refining high-aluminum clays, but the Bayer process is still the only economical commercial and standard method for producing aluminum from bauxite in the near future (Pindyck, 1977); 3) in this study, potential dates of the supply restriction are assumed to be 1984, hence no technological change in that year is justified; 4) this study is focused on short-term impact analysis rather than long-term impact analysis.

The last and major stage of the study is the analysis of the optimal sectoral adjustment and optimal resource allocation pattern during a supply restriction. The study in this stage will link the I-O model and LP technique to analyze the impact of a supply restriction and evolve a strategy for choosing feasible and optimal packages for economic policies. Rather than to search for the optimal development planning pattern, the purpose of the LP model is simply to explore the impact of a supply restriction and identify optimal responses of the sectors under alternative assumptions about the availability of commodity supply in order to derive the optimal allocation function. A thirty-four sector model is presented in this study. Optimal adjustment programs are obtained by maximizing gross domestic product (GDP) in the year that the supply restriction occurs. The balance of payments constraint together with limitations on domestic scarce resources, private consumption, and export activity are included. But some of these constraints will be removed when a serious disruption is assumed. The main variables for which optimal adjustment value for the supply disruption period are investigated are the level of the sector's domestic output, final demand, and the optimal allocation coefficients. Substitution effects are also incorporated in this stage. The optimal solution without a supply restriction is used as a baseline for comparison. The results of the study will present a basic framework for economic policy recommendation during the supply restriction. Figure 1.1 is a diagrammatic representation of the interrelationships of the stages of this study.

D. ORGANIZATION AND LIMITATIONS

There are nine chapters in this dissertation. Chapter II describes the role of aluminum in the world and Taiwan economies and presents a linkage analysis of the aluminum sector in Taiwan. An econometric demand model for the Taiwan aluminum industry is developed in Chapter III. Chapter IV examines the possibility of substitution between aluminum and copper commodity inputs. Methodologies for analyzing

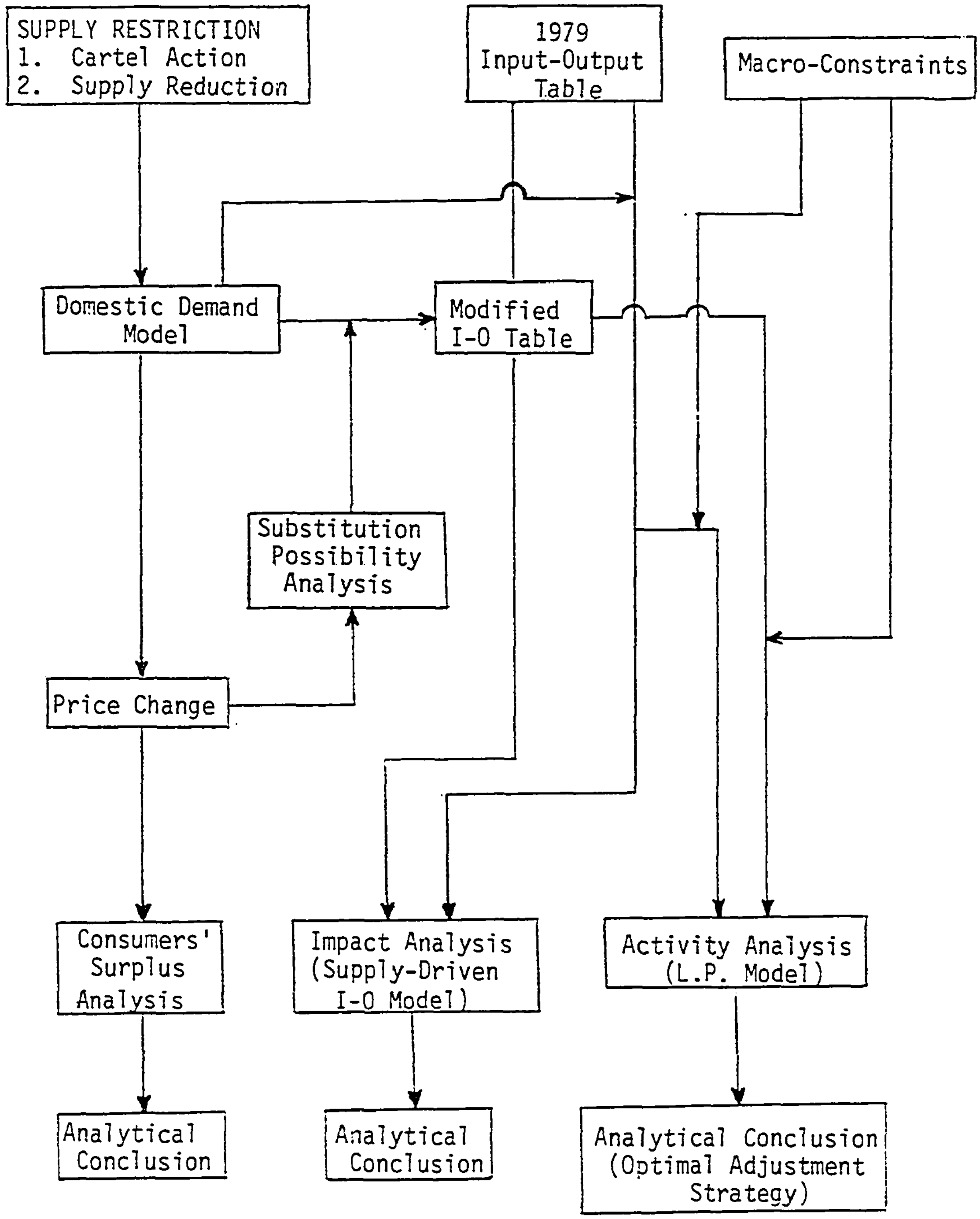

Figure 1.1

DIAGRAMMATIC REPRESENTATION OF THE STUDY FRAMEWORK supply restriction impacts are presented in Chapter V. The consumer surplus approach and the I-O model are discussed; their analytical results are shown in Chapter VI. In Chapter VII, the methodology for planning the optimal adjustments to supply restrictions are presented. The model employs linear programming to optimize GDP during a supply restriction, and it illustrates how the I-O model and linear programming technique can be linked together to solve the restricted resource allocation and optimal adjustment problem. The results of the linear programming model and their duals are discussed in Chapter VIII. The optimal restricted resource allocation functions are derived from the results. The conclusions of the study are presented in Chapter IX. Several appendices are also presented, in which the data base, an overview of the Taiwan economic situation, the method of disaggregating and aggregating the 1979 Taiwan I-O table and the table itself are described.

In addition to the limitations of I-O model itself,* the more important limitation of this study is that it is restricted in the set of substitution possibilities. Copper is not the only substitute for aluminum; other materials such as steel and plastic are also substitutes for aluminum, but are not considered here. Another important limitation is that since detailed (sectoral) data are not easy to obtain, the study of domestic demand for aluminum and substitutability between aluminum and copper are therefore restricted

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*The reader interested in a detailed discussion of the limitations of an I-O model is referred to Appendix B.

to aggregate econometric models. In spite of these limitations, the analytical framework used here still provides a very powerful tool for examining the economic impact of supply restriction and presenting the optimal pattern of adjustment at that time.

CHAPTER II

THE ROLE OF ALUMINUM IN THE WORLD AND TAIWAN ECONOMIES

A. INTRODUCTION

The purpose of this chapter is to provide some background on the aluminum industry that will be useful in specfying models to determine the impact of a supply restriction. The discussion will focus on two aspects. The first aspect is the structure and performance of the world aluminum industry. This knowledge is essential to determining the likelihood and scope of an aluminum supply restriction. We will begin by examining world reserves, production and demand. The discussion will then move to the aluminum cartel and its behavior. The extent of the dependence of Taiwan on alumina/bauxite imports will also be shown.

The second aspect is the role of aluminum in the Taiwan economy. This knowledge is very important for measuring the potential impact of an aluminum supply restriction on the Taiwan economy. We will examine the aluminum market structure in Taiwan and how it has been affected by government policy over time. The backward and forward linkages between the aluminum sector and the remainder of the Taiwan economy will be computed in order to show the importance of aluminum supply availability.

Aluminum is the most abundant metal in the earth, but bauxite ores* account for a relatively small part of the total aluminum resources

*Bauxite is defined as aggregates of aluminous minerals and more or less impure, in which aluminum is present as hydrated oxides (Patterson, 1977).

of the world. Alternative technologies are available for extracting aluminum from non-bauxite sources, but the processing costs are extremely high (Pindyck, 1978). Hence, bauxite is still the primary source of aluminum manufactured under the present technology. Bauxite is first processed into alumina by the Bayer process, and then processed into aluminum by an electrolytical process.*

A study prepared by the World Bank (Brown, et al., 1983) indicates that there are three major components of alumina production costs. The first is the cost of capital. Because alumina production is capital intensive, the cost of capital accounts for about 33 percent of alumina costs. The second component is the cost of delivered bauxite,** which represents 26 to 28 percent of alumina costs. Energy constitutes another major component of alumina costs, accounting for 18 percent.

In aluminum smelting, alumina, energy and capital cost constitute the most important cost elements. Alumina represents about 30 percent of aluminum smelting costs; capital cost accounts for 16 to 35 percent; and energy (electricity) varies from 16 to 30 percent of aluminum smelting costs.*** As we will show below, changes in major cost com-

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*There are three electrolytical processes for aluminum smelting: the Hall-Heroult process, the Quebec process and the Pechiney process. However, only the Hall-Heroult process has been large-scale commercially successful to date (CRA, 1976).

**The delivered bauxite cost includes ocean transport costs and the bauxite levy.

***The variation of the cost is attributable to the regional characteristics, the electricity cost in the region, and the ore grade.

ponents have had profound implication for the viability of several aluminum processing operations. Moreover, given that the cost of energy constitutes a large proportion (21 to 35 percent) of total aluminum smelting costs, capacity expansion investment in the aluminum industry in the future will lean toward locations having lower cost energy (electricity supplies).

B. THE WORLD ALUMINUM INDUSTRY

The major bauxite reserves and production are located in Guinea, Australia, Brazil, Jamaica, Guyana, Indonesia, Ghana, and Surinam. Guinea, Jamaica, Surinam, Guyana, and Indoesia are the major bauxite exporting countries. Table 2.1 shows world bauxite reserves and production in 1980, and estimates production capacities in the year 2000. The table indicates that for 1980, the eight countries with the largest bauxite reserves account for 79.7 percent of the total world reserves and 72.1 percent of total world production. These countries are projected to account for 73.6 percent of total world production capacity in the year 2000. This fact implies that these eight countries are expected to continue to maintain their prominence in the next two decades. From the concentration ratios provided in Table 2.1, we can draw similar inferences about the largest four countries in terms of reserves, production, and production capacities.

In order to maximize economic rents from the exploitation and processing of bauxite and to promote the rational development of the

Table 2.1

WORLD BAUXITE MARKET STRUCTURE IN 1980 AND 2000

Country	Reserves, 1980 Level (10^6 tons)	Reserves, 1980 Share (percent)	Production, 1980 Level (10^6 tons)	Production, 1980 Share (percent)	Capacity, 2000 Level (10^6 tons)	Capacity, 2000 Share (percent)
Guinea	5,500	24.2	13.3	14.5	23.0	11.5
Australia	4,600	20.2	27.2	29.6	34.2	17.2
Brazil	4,070	17.9	4.2	4.6	8.7	4.4
Jamaica	1,592	7.0	12.1	13.2	47.6	23.8
Guyana	700	3.1	3.1	3.4	9.5	4.8
Indonesia	700	3.1	1.2	1.3	13.4	6.7
Surinam	490	2.2	4.9	5.3	5.3	2.7
Ghana	500	2.2	0.2	0.2	5.3	2.7
Subtotal	18,152	(79.7)[a]	66.2	(72.1)	147.1	(73.6)
CR(4)[b]		(69.3)		(62.6)		(59.2)
IBA[c]		(61.8)		(67.5)		(69.2)
U.S.	40	0.2	1.5	1.6	1.9	1.0
USSR	300	1.3	10.1	11.0	18.1	9.0
Other	4,280	18.8	14.0	15.3	32.9	16.5
Total	22,772	100.0	91.8	100.0	200.0	100.0

Sources: World Bank (1982); Brown, et al. (1983).

[a]Numbers in parentheses not included in the totals.
[b]CR(4) is the concentration ratio for the largest four countries.
[c]IBA contains the members of the International Bauxite Association in the subtotal.

bauxite industry, the International Bauxite Association (IBA) was formed at the governmental level in Jamaica, Surinam, Australia, Guinea, Guyana, Sierra Leone, and Yugoslavia in 1974. Regular meetings are held to discuss issues on bauxite pricing and production levels. By 1980, IBA was expanded to eleven bauxite producing countries, adding Indonesia, Dominican Republic, Haiti, and Ghana. It now represents more than 83 percent of total bauxite economic reserves in the world and more than 70 percent of total bauxite production (more than 80 percent of total non-communist world bauxite production). Moreover, IBA is expected to account for more than 78 percent of total non-communist world bauxite production capacity in the year 2000 (Brown, et al., 1983).

From the perspective of individual firms the aluminum industry is also a highly concentrated, vertically and horizontally integrated industry. The worldwide primary aluminum industry is dominated by six large vertically integrated companies: Alcoa, Alcan, Reynolds, Kaiser, Pechiney, and Alusuisse. These companies account for over 60 percent of the production capacity in the world for bauxite and alumina, and over half of the total aluminum capacity, excluding the communist countries (World Bank, 1982; p. 63). However, some independent producers emerging in the past few years may have long-term effects on the market structure in the aluminum industry (Brown, et al., 1983). One of the effects is a decrease in the degree of concentration of the industry.

Because of the industry's vertical integration and the long-run contracts among buyers and sellers, there are no real market prices for bauxite. Prices are mainly a transfer price within an integrated company and vary according to production cost, government taxes, and ore grade. Primary aluminum is principally traded at prices established by producers.* Since the producers generally practice mark-up pricing (U.S. Permanent Subcommittee on Investigation, 1974), producers' prices are directly proportionate to production costs. This fact also implies that any increase in the bauxite price will significantly affect aluminum producers' prices.

C. POSSIBILITY OF ALUMINUM SUPPLY RESTRICTIONS

In general, a successful cartel in the long-run requires that each member have a similar level of economic development and compatible political orientation, and constrains any member from earning higher revenues than the others. However, these conditions do not hold for each member in IBA. In addition, since bauxite is a relatively abundant mineral and is found in many countries, any increase in bauxite price may stimulate new supplies from outside the IBA, and obstruct the success of a cartel action. Therefore, one may argue that a bauxite cartel cannot develop and succeed in the future. However, this may not be true in the short-run. Pindyck (1978) calculated the ratios of the sum of discounted profits for a monopoly cartel to that of a competitive market. He found that the ratio for bauxite (1.63) is higher than that for oil (1.54). This fact implies that the

*World Bank (1982). About 80 percent of primary aluminum trade is based on producer or list prices, though dealer or free market prices are also quoted. The London Metal Exchange has been quoted for spot and three month contracts since 1977.

potential incentive for cartel action in the world bauxite market is very significant. The success of high tax levies imposed by IBA in 1974 also conceals the possibility of dramatic increases in the bauxite price in the near future. Besides, an analysis for the possibility of commodity supply restrictions by the U.S. Department of the Interior (Enzer, 1978) also indicates that bauxite would become the commodity with the greatest possibility of a supply restriction during the period 1984-1987.* Although this study is done from a U.S. standpoint, any supply restriction for the United States will have an immediate effect on the world aluminum industry because the United States is the largest bauxite importing country.** Therefore, the potential of cartel actions will not disappear if the world economic and political situation is continually unstable.

D. THE ALUMINUM MARKET STRUCTURE IN TAIWAN

In 1979, total domestic consumption of aluminum in Taiwan was 115.9 thousand tons, including 102.6 thousand tons of primary aluminum, and 13.8 thousand tons of aluminum scrap. Total consumption represents an increase of 389 percent over 1971. The ratio of aluminum consumption to GNP (at 1979 price level) was 0.10 ton/NT$ million,*** an increase of more than 100 percent in a decade. Most

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*The probability of an aluminum supply disruption in the periods 1984-1987 estimated by U.S. Department of the Interior was around 10 percent (Enzer, 1978).

**Based on the study by the World Bank (1982; p. 78), the United States imported 14.274 million tons of bauxite in 1980, which accounted for 38.5 percent of the total world gross bauxite imports.

***NT$ refers to New Taiwan dollars. US $1.00 equaled to NT $40.00 in June 1984.

of the aluminum consumed is used in the construction and building industry, electrical engineering industry, transportation equipment, containers and packaging, and consumer durables. Table 2.2 shows a breakdown of aluminum consumption by end uses in 1979. Based on the Taiwan I-O table in 1979, the construction and building industries, the largest aluminum consumers in Taiwan, accounted for 41.6 percent of total aluminum consumption. Electrical goods and transportation equipment accounted for 23.1 and 12.8 percent, respectively.

To achieve this domestic aluminum consumption, Taiwan must import all of the required bauxite, most of the aluminum scrap, and around 50 percent of its total primary aluminum.* Aluminum scrap is mainly imported from the United States. The main suppliers of bauxite are Malaysia, which accounted for 84 percent of total bauxite imported, and Australia, which accounted for 15 percent. The main overseas suppliers of primary aluminum are the United States and Japan, which accounted for 42.1 and 31.5 percent, respectively, of total primary aluminum imported. In 1980, Taiwan imported 0.26 million tons of bauxite.** All of it was used by the government-owned Taiwan Aluminum Corporation (Talco). Table 2.3 lists total aluminum supply and consumption from 1971 to 1980.

Talco, an integrated company, was established in May 1946. At that time, the capacity of primary aluminum production was only four

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*Another 50 percent of total aluminum required comes from the domestic primary aluminum industry (where production is from imported bauxite).

**All information in this paragraph is based on the data in the Mineral Yearbook (1981).

Table 2.2

CONSUMPTION OF ALUMINUM BY END USES, 1979

Industry	A (percent)	B (percent)
Construction	43-47	41.6
Electrical Engineering	16-18	23.1
Transportation	7-10	12.8
Containers and Packagings	10-12	22.5
Consumer Durables	6-8	
Others	5-18	

Sources: Column A--estimated from data in Metallic Materials in Taiwan, R.O.C., Science and Technology Advisory Group, Executive Yuan, R.O.C., August 1980. Column B--estimated from data in the modified 1979 Taiwan I-O table.

Table 2.3

TOTAL ALUMINUM SUPPLY-DEMAND FROM 1971-1980

Year	Domestic Ingot Production	Imports[a]	Exports	Total[b] Supply	Total[c] Demand
1971	26,500	8,637	5,200	30,300	29,800
1972	32,100	12,100	8,972	35,228	34,328
1973	35,100	30,500	6,400	59,200	51,900
1974	31,300	31,700	7,400	55,600	47,300
1975	28,100	19,500	5,200	42,400	50,100
1976	25,500	46,800	3,100	69,200	64,300
1977	29,700	64,800	9,100	85,400	79,200
1978	50,300	66,000	8,100	108,200	108,200
1979	56,218	66,622	6,943	115,897	115,897
1980	63,549	77,575	7,456	133,568	133,668

Sources: Data from 1971 to 1978 based on Metallic Materials in Taiwan (1980), data for 1979-1980 comes from Mineral Year Book (1981).

[a]Import includes ingot and scrap.
[b]Total supply = domestic output + imports - exports
[c]Total demand from 1971 to 1977 has been modified by inventory change.

thousand tons per year. In order to assume its main function to produce aluminum and fabricated aluminum products for the local market, Talco has completed two major expansion projects. The first one, completed in 1972, increased the capacity of Kaohsiung I smelter to 38,000 tons-per-year of aluminum. The second expansion project, completed in 1980, resulted in construction of Kaohsiung II smelter with an annual capacity of 50,000 tons-per-year. The total capacity of primary aluminum production was 85,000 tons per year. Unfortunately, the Kaohsiung I facilities encountered numerous difficulties after 1974, including power shortages and a substantial increase in energy cost with the result that the operation of Kaohsiung I became more inefficient. Besides, in order to alleviate the effect of the increase in energy cost on its financial position, Talco considered branching more into fabricated products including aluminum foil, aluminum sheets, and other aluminum products. In 1981, Talco had a 46,000 tons-per-year rolling mill and a 50,000 tons-per-year extrusion plant, and further capacity expansion of the rolling mill was expected in 1983. However, due to the further increase in energy cost in 1979* and a serious pollution problem, Kaohsiung I was finally forced to shut down in early 1981 (Chin, 1981). The capacity of primary aluminum production was thus reduced to 50,000 tons-per-year.** Primary aluminum supply in Taiwan in the future will therefore be highly

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*This is because of further increase in OPEC price in 1979. Taiwan imported 82.6 percent of its total energy requirement in 1979.

**The information summarized in this paragraph comes principally from the Mineral Yearbook (1973-1981).

dependent on imports. This dependence will also increase the vulnerability of the Taiwan economy to aluminum supply restrictions induced by world supply disruptions or foreign supply actions.

As indicated above, the domestic primary aluminum industry is dominated by Talco, the country's sole producer of primary aluminum, which is vertically integrated from the processing of bauxite into alumina to the production of primary aluminum products. Owing to the dramatic increase in the cost of electricity, its monopoly advantage is offset by a price disadvantage when compared to imported aluminum. The cost per kilwatt-hour of electricity of Talco was NT$2.16 in 1981, compared with NT$0.57 in the United States and about NT$0.95 in western Europe (Mineral Yearbook, 1981). Talco was forced to maintain a cash price of NT$66,111 per ton of ingot in order to compete with imported aluminum in 1981, losing NT$20,770 per ton for aluminum produced by Kaohsiung I and NT$7,477 for aluminum produced by Kaohsiung II (Bank of Communications, 1983). Talco's production costs and list prices are shown in Table 2.4.

Since all of the bauxite and around 50 percent of the primary aluminum required must come from foreign suppliers, any substantial change in the world aluminum market would seriously affect the Taiwan aluminum market and the whole Taiwan economy. The following sections will discuss the interindustry relationship of the aluminum sector in Taiwan and economic importance of the major users of aluminum.

Table 2.4

PRODUCTION COSTS AND LIST PRICES OF TALCO
(NT$)

Year	Average Production Costs		Domestic[a] Price	US Producer's[b] Price
	Koahsiung I	Kaohsiung II		
1980	76,405	57,501	80,633	67,048
1981	86,881	73,588	66,111	76,714
1982	--	87,337	65,125	50,507[c]

Sources: Survey of Manufacturing in Taiwan (1983); Industry of Free China (1983); World Bank (1982).

Note: US $1.00 equaled to NT $36.06 in 1980, NT $37.89 in 1981, and NT $39.00 in 1982.
US producer's price did include transportation and loading cost (US $100/ton), harbor due (4%), and tariff (10%).

[a]List prices of Talco, aluminum ingots 99 percent purity.

[b]List prices of US producer, 99.5 percent purity.

[c]Free market price, 99.5 percent purity. This price level resulted from over supply in 1982.

E. LINKAGE ANALYSIS

Linkage analysis may illustrate the relationship between a sector and other sectors in an economy and provide insights into the impact of any sectoral change on the economy. The linkage effects between a sector and the economy may be backward or forward. A backward linkage may be determined by a sector's purchase of intermediate inputs from all sectors for producing one unit of the sector's output. This linkage shows the impact on the economy due to production of one unit output in the sector. A sector with a larger backward linkage coefficient implies that relatively more economic outputs will be created by increasing production of the sector. A forward linkage is determined by those sales from the producing sector to all sectors which use it as an input to produce their output. The forward linkage shows the impact on the economy due to the supply availability of the sector in question and indicates the importance of the sector's supply availability to stimulate the output of all other sectors. Thus, backward linkage analysis tells us which sectors deserve more incentive to encourage their production or to increase the demand for their outputs in order to speed up economic growth. Forward linkage analysis presents the impact of supply availability of a sector's output on other sectors in the economy.

Calculation of backward (Chenery, 1958) and forward linkage coefficients for each sector may be defined as follows:

$$(2.1) \qquad BL_j \text{(Backward linkage coefficient)} = \sum_i \frac{X_{ij}}{X_j}$$

(2.2) $$FL_i \text{(Forward linkage coefficient)} = \sum_j \frac{X_{ij}}{X_j}$$

where X_{ij} = sales of sector i to sector j

X_j = total output of sector j

However, the above measures only reflect the direct linkages among the sectors and take no account of the indirect intersectoral effects on the economy. To measure both effects (direct and indirect effects), we can extend the analysis to an I-O framework.

A detailed discussion of I-O analysis will be presented in Chapter V. Briefly, for now, the balance equation of the I-O model used to derive these linkage coefficients is as follows:

(2.3a) $$X - AX = F - M$$

or

(2.3b) $$X = (I-A)^{-1}\ (F-M) = (I-A+M^d)^{-1}\ F = BF$$

$$B = (I-A+M^d)^{-1}$$

and

(2.4a) $$X - D'\ (X+M) = V$$

or

(2.4b) $$X = (I-D'(I+M^d))^{-1}\ V = GV$$

$$G = (I-D'(I+M^d))^{-1}$$

where X is a vector of gross output; F is a vector of final demand; M is a vector of imports; A is the input coefficient matrix, whose element (a_{ij}) shows the amount of inputs required from sector j to produce one unit output of sector i; D is the allocation coefficient matrix (Ghosh, 1958), whose element (d_{ij}) represents direct sales from sector i to sector j per unit output of sector i; D' is the transpose of the matrix D ; V is a vector of primary inputs; M^d is a diagonal matrix representing the ratio of the import and domestic output for each sector. Each element (b_{ij}) in the inverse matrix (B) represents the total input required from sector j to deliver one unit output of sector i to final demand. The element (g_{ij}) in the inverse matrix (G) represents the total output increase in sector i due to one unit change in primary inputs of sector j.

The measure of total backward linkages (including direct and indirect linkages) for each sector is the column sum of the inverse matrix (B), which shows the total changes in economic gross output related to one unit change in final demand for a sector's output. The measure of total forward linkages is the column sum of the inverse matrix (G), which shows the total changes in economic gross output related to unit change in primary inputs of the sector in question (Bulmer-Thomas, 1982).*

In order to obtain the relative linkage index for comparison, a normalization procedure is often carried out by the following methods (Bulmer-Thomas, 1982):

(2.5) $$BL^r\text{(Backward linkage index)} = \frac{\frac{1}{n}\sum_i b_{ij}}{(\frac{1}{n})^2 \sum\sum_{ij} b_{ij}}$$

(2.5) $$\frac{1}{n}\sum_i \quad (\frac{1}{n})^2 \sum\sum_{ij} b_{ij}$$

$$FL^r\text{(Forward linkage index)} = \frac{\frac{1}{n}\sum_i b_{ij}}{(\frac{1}{n})^2 \sum\sum_{ij} g_{ij}}$$

*Two approa[illegible]rward linkages. One is based on [illegible]d is based on the method presented here. However, from the supply side standpoint, the latter approach is more appropriate to show total forward linkages (Bulmer-Thomas, 1982).

where b_{ij} and g_{ij} are defined as above, and n is the number of sectors. These linkage indexes will show us the relative stimulus for the whole economy. If BL^r or FL^r is greater than 1, it implies a sector with relative higher linkages (above the average) and relative higher potential stimuli to growth via the inducement mechanism; while BL^r or FL^r is less than 1, it implies a sector with relative low linkages (below the average) and relative low stimuli to economic gross output (Bulmer-Thomas, 1982). In the next section, we will calculate the backward and forward linkages for the aluminum sector based on the formulations represented above.*

The backward and forward linkages are computed for the aluminum sector based on the modified 1979 Taiwan I-O table (34 sectors). The original 1979 I-O table (49 sectors) did not isolate the aluminum sector, in which sector 36 contains aluminum, miscellaneous metals, and non-ferrous products sectors together. Thus some modification procedures are necessary in order to isolate the aluminum sector and simplify the calculation. First, the 36th sector in the original I-O table was disaggregated into the aluminum miscellaneous metals, and non-ferrous products sectors. Second, the disaggregated 1979 I-O

---

*However, there are some major inherent problems in linkage analysis. First, the potential stimulus measured by backward and forward linkages may not happen because of unavailability of complementary inputs and possibility of being absorbed as increased imports rather than increased domestic output. Second, these measures of linkages may conflict with the income-generation objective which is the main objective for most developing countries. Third, these measures do not consider efficiently or comparative cost among sectors. For a detailed discussion of these problems, see Bulmer-Thomas (1982) and Hewings (1982).

table was aggregated from 51 sectors to 34 sectors. Detailed discussion regarding the disaggregation and aggregation methods is presented in Appendix B. This modified 1979 Taiwan I-O table (34 sectors) will be used throughout the study.

Precentage distribution of input purchases by the aluminum sector (i.e., the input coefficient column for aluminum sector) is set in the first column in Table 2.5. This column identifies all intermediate inputs used by the aluminum sector and shows their percentage distribution. Output distribution of the aluminum sector (i.e., the supply coefficient row for aluminum sector), which is also presented in percentage form, is listed in the second column. This column indicates the major aluminum using sectors. The backward linkages are presented at the bottom of the first column and the forward linkage is shown at the bottom of the second column. The numbers in parentheses show the relative linkage indexes.

From the first column, we find that the input of electricity, the largest input, accounted for 13.2 percent of the total value of intermediate inputs to the aluminum sector in 1979; other industrial chemicals accounted for 4.7 percent; petroleum refining products, 4.5 percent; and wholesale and retail trade service, 4.2 percent. Bauxite and other minerals accounted for only 1.6 percent of total production cost. That means that an increase in the energy price has a much greater effect on the domestic aluminum price than does an increase in the bauxite price. The size of the direct backward linkages for the aluminum sector is 0.88, while the total backward linkages is

Table 2.5

LINKAGES FROM ALUMINUM SECTOR

Code	Sector	Percentage Distribution of Inputs Purchased by Aluminum Sector	Percentage of Total Aluminum Sector's Output Used by Each Sector
1	Agriculture	0.0	0.0
2	Livestock	0.0	0.0
3	Forestry	0.0	0.0
4	Fisheries	0.0	0.0
5	Coal & Coal Products	0.1	0.0
6	Crude Oil & Natural Gas	0.0	0.0
7	Other Minerals	1.6	0.0
8	Food Manufacturing	*	0.2
9	Textile & Apparel Accesories	0.1	0.1
10	Wood & Wood Products	0.6	*
11	Pulp Paper & Allied Products	0.8	0.5
12	Rubber & Rubber Products	*	*
13	Petrochemical Raw Materials	*	0.0
14	Other Industrial Chemicals	4.7	*
15	Chemical Fertilizer	0.0	0.0
16	Plastics & Plastic Products	0.1	1.1
17	Misc. Chemical Manufactures	0.3	0.6
18	Petroleum Refining Products	4.5	0.0
19	Cement & Cement Products	*	0.0
20	Misc. Non-metal Mineral Prods.	0.6	0.0
21	Steel & Iron	0.5	*
22	Aluminum	49.4	32.1
23	Miscellaneous Metals	0.8	0.1
24	Metallic Products	0.3	24.9
25	Machinery	0.7	2.8
26	Electrical Apparatus & Equip.	0.2	16.3
27	Transport Equipment	0.1	10.4
28	Miscellaneous Manufactures	*	1.6
29	Construction	0.1	2.2
30	Electricity	13.2	0.0
31	Gas & City Water	0.1	0.0
32	Transportation & Communication	1.2	0.0
33	Wholesale & Retail Trade	4.2	0.0
34	Miscellaneous Services	3.6	0.7
Direct Linkages		0.88	0.94
Total Linkages		1.82 (0.97)[a]	6.17 (1.31)[a]

Source: Compiled from the modified 1979 Taiwan I-O table.
*less than 0.1 percent
[a]the number in parentheses represents the relative linkage index

1.82. The relative backward linkage index for the aluminum sector is 0.97, which is only slightly less than 1.0. This figures implies that the aluminum sector has relative fewer backward links than other sectors.

The total aluminum supply in value terms was NT$10,554 millions in 1979. From the second column in Table 2.5, we find that 32.1 percent of that supply was used in intra-aluminum sector production; 24.9 percent in metallic products; 16.3 percent in electrical apparatus and equipment; 10.4 percent in transportation equipments; and 2.2 percent in construction sector. The forward linkages from the aluminum sector is relative higher among the sectors in the economy. The direct and total forward linkages from the aluminum sector are 0.94 and 6.17 respectively. The relative forward linkage index is 1.31, which is greater than 1, which implies that the aluminum sector has relative higher forward linkages. From that column, we also find that the largest forward linked sectors are aluminum sector itself and the metallic products sector. This fact indicates that there exists a further processing linkage for the aluminum sector. If the second round of forward linkages is included, the linkage profile will be much different and the construction and electrical apparatus sectors will become the largest end users of outputs of the aluminum sector, as indicated in Table 2.2.

Because the relative backward linkage index is less than 1.0 and the relative forward linkage index is greater than 1.0, we can conclude that the availability of aluminum supply is very important to the growth in economic gross output, but domestic production of aluminum sector is not. From one perspective, this fact justifies a change in government policy to increase aluminum importation and suspend the expansion of domestic primary aluminum production. Of course, this conclusion must be weighed against a number of other considerations favoring aluminum self-sufficiency.

CHAPTER III

AN ECONOMETRIC DEMAND MODEL OF THE TAIWAN ALUMINUM INDUSTRY

A. SPECIFICATION OF THE MODEL

In the case of the aluminum industry in Taiwan, price is taken as given, because aluminum imports into the country accounted for only 1.3 percent of world trade in 1980, which is too small to influence world aluminum prices. Because of this small proportion, we can also assume that aluminum supply in Taiwan is perfectly elastic, which means that, given the price level, the supply level will be completely determined by the demand and exactly equal to the demand level. In other words, any change in the quantity of domestic demand for aluminum will bring forth an equivalent change in the quantity of aluminum supply. Figure 3.1 shows the relationship between the domestic aluminum market and the world aluminum industry. S^W and D^W represent the world demand and supply curves respectively and P^W is the equilibrium world aluminum price. D^d is the domestic demand curve. Based on the above discussion, only the domestic demand model will be estimated in this chapter. The price and supply of aluminum will be treated as exogenously determined.

In Chapter II, we analyzed the market structure of the aluminum industry in Taiwan and found that almost all of the aluminum is used in the production of other goods rather than for final consumption. Therefore, the quantity of aluminum demanded is derived from the demand for final goods rather than the demand for aluminum itself. Accordingly, the derivation of the demand equation for aluminum is based

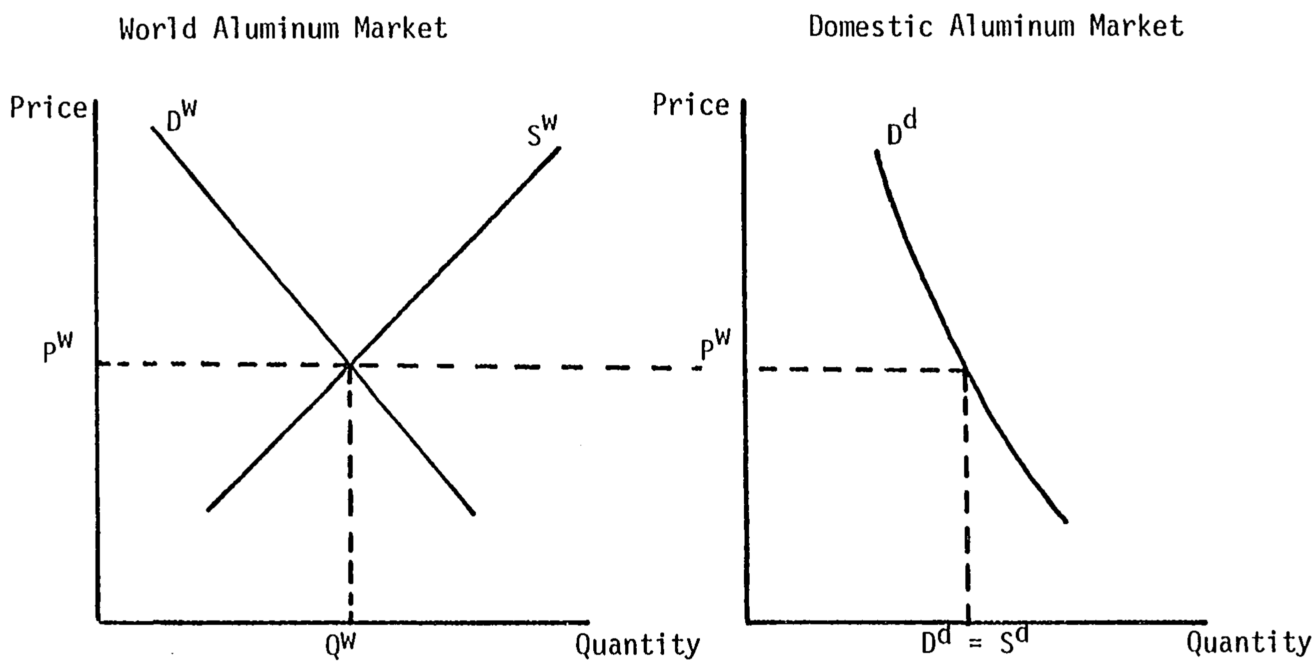

Figure 3.1

RELATIONSHIP BETWEEN THE DOMESTIC AND THE
WORLD ALUMINUM MARKETS

on the production function for final goods via duality theorems. The main purpose of this estimation is to obtain the price elasticity of demand so that we can estimate price changes and the consumers' surplus loss due to a supply restriction.

We assume that there exists an aggregate production function:

(3.1) $$Q = f(X)$$

where X is the aggregate physical output that can be produced using the non-negative vector of inputs X. Based on the marginal productivity theory of input demand, the cost minimizing and profit maximizing demand for input x_i should be at the level at which the value of marginal product of the ith input ($P^* MP_i$) is equal to the price (P_i) of the ith input, which is defined as follows:

(3.2) $$P * MP_i = P_i$$

where P is the price of the output (Q), and MP_i is the marginal product of the ith input (x_i), which is a function of the output and the input (x_i).* The marginal product is equal to the partial derivative of the production function with respect to the ith input x_i, namely

(3.3) $$MP_i = \frac{\partial Q}{\partial x_i} = g(Q, x_i)$$

---

*It is easy to prove that the marginal product of the input is a function of output and the input level of x_i. For example, if the production function is a Cobb-Douglas production function:

$$Q = B \prod_{j=1}^{n} X_j^{r_j}$$

then

$$MP_i = \frac{\partial Q}{\partial x_i} = B \cdot r_i X_i^{-1} \prod_{j=1}^{n} X_j^{r_j} = \frac{r_i}{X_i} Q = f(X_i, Q)$$

It is also true for the CES and other production functions.

If we insert equation (3.3) into (3.2), then

$$(3.4) \qquad P_i = P * \frac{\partial Q}{\partial x_i} = g(Y, x_i)$$

where Y is the value of the output (Q). Taking the inverse of equation (3.4)

$$(3.5) \qquad x_i = q(Y, P_i)$$

Equation (3.5) shows that the demand for the input x_i is a function of the total value of the gross output and the price of the input itself. If we consider the substitution effect between inputs, equation (3.5) will become

$$(3.6) \qquad x_i = q(Y, P_i, P_s)$$

where P_s is the price of substitutes for x_i. For estimation purposes, the log-linear specification for the demand function is employed:

$$(3.7) \qquad \ln x_{i,t} = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_{i,t} + \beta_3 \ln P_{s,t} + u_t$$

where t is time, and u is stochastic error. The advantage of the log-log form is that the elasticities are simply the coefficients of individual variables. Equation (3.7) will be used for the estimation of the demand model for aluminum, presented in Section C.

B. THE DATA

Because time series data on the demand for aluminum on a sector-by-sector basis are not available, the derived demand equation is estimated for total domestic consumption rather than for the individual sectors. In the estimated equation, gross domestic output is used as a proxy for the value of output contained in equation (3.7). Instead of the domestic aluminum producer's price, however, the aluminum price variable is based on the U.S. producer's list price for 99.5 percent purity and delivered aluminum ignots in NT dollars per ton. The NT dollar base is derived as follows:

(3.8) NT$/ton = U.S.$/ton (U.S. list price) * Exchange rate

The reasons for using U.S. prices instead of domestic prices are that: (1) as indicated in Chapter II, domestic prices have been distorted by a government subsidy since 1974 (U.S. prices are not perfectly competitive, but are less distorted); (2) most of imported aluminum comes from the United States and the import ratio is expected to increase substantially; (3) the U.S. price provides the best result in our estimation.*

There is an apparent problem in using the U.S. producer's price when we analyze the consumers's surplus loss in Chapter VI based on the demand model here, because the U.S. producer's price does not include the transportation cost. However, if we compare the U.S. producer's price with the actual delivered price (transaction price) during the time period, we find that actual delivered prices are both above and below U.S. producer's prices because of variation in transportation cost as well as aluminum prices on spot and short-term contract bases. Therefore, for predictive purposes, we assume the U.S. producer's price used here does include the transportation cost.**

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*The U.S. price was also used in estimating aluminum demand for many countries and areas by the World Bank (1983) and Smithson (1979).

**Actually, the failure to more accurately measure the transportation cost during the estimated time period may be a shortcoming in calculating the consumers' surplus analysis. However, failure to accurately account for transportation costs does not appear to cause serious problems in estimating aluminum demand.

In the case of aluminum, the primary related commodity is copper, because aluminum and copper are the closest mutual substitutes.* The data for price of copper are based on the current dollars at London Metal Exchange for copper wirebars. It is also converted into NT dollars. Each index is deflated by the wholesale price index (1979 = 1.00) in Taiwan. The indices are therefore in constant 1979 NT dollars. The basic data for the variables in equation (3.7) are presented in Appendic C. The period 1971-1980 is covered in the estimation.

C. THE ESTIMATION RESULTS

Before the estimation of the equation specified in Section A, some clarification is necessary. For most demand models, the supply equation should be considered in order to estimate both equations simultaneously. Otherwise, the demand equation may not be identified and estimators for the parameters of the equation may be inconsistent (Maddala, 1976; p. 221). As mentioned earlier, the aluminum supply in Taiwan is assumed to be perfectly elastic and exogenously given. Therefore, the demand equation (3.7) will be exactly identified and estimable. Besides, the price is taken as given in the Taiwan aluminum industry, thus no endogenous variables are implicitly included in the left hand side of the demand equation. The assumption of no correlation between the price variable and the error term is therefore appropriate.

Based on the above assumptions, equation (3.7) can be estimated by ordinary least squares to obtain consistent and unbiased estimates

*See the National Materials Advisory Board's Mutual Substitutability of Copper and Aluminum.

of the parameters. The final result of the estimation of the parameters of the derived demand equation is presented as follows:

(3.9) $\ln X_{A,t} = -9.57 + 2.02 \ln Y_t - 0.64 \ln P_{A,t}$

s.e.	(2.85)	(0.14)	(0.24)
t	-3.36	14.79	-2.70

$\bar{R}^2 = 0.97$ F = 109.31 DW = 2.15

where $X_{A,t}$ = total domestic aluminum consumption

Y_t = real gross domestic product

$P_{A,t}$ = real U.S. price for aluminum in NT dollars

Because the copper price variable is not significant, it was dropped from the estimating equation. In general, the domestic demand equation seems to be appropriate. The sign for each parameter is consistent with that predicted theoretically. Based on the value of t ratios, the estimate of Y is significant at the 1 percent significance level for one tailed tests, while the estimate of P_A is significant at the 5 percent significance level. The adjusted multiple coefficient of determination ($\bar{R}^2$) is equal to 0.97. The Durbin-Watson statistic is 2.14, which suggests no autocorrelation of the error term. Therefore, the result of the estimation is generally good. From the estimated equation, we find the price elasticity is -0.64 and the output or income elasticity is 2.02. The income effect is much higher than the price effect on aluminum demand. Table 3.1 shows the actual and estimated domestic demand for aluminum for the period 1971-1980. The average percentage error found, which is less 5 percent, is very low

Table 3.1

HISTORICAL SIMULATION RESULTS OF DOMESTIC ALUMINUM DEMAND

Year	Actual	Estimated	% Error
1971	29,800	25,999	12.8
1972	34,338	37,482	9.2
1973	51,900	50,961	1.8
1974	47,300	46,991	0.7
1975	50,100	52,697	5.2
1976	64,300	68,321	6.3
1977	79,200	81,548	3.0
1978	108,200	111,564	3.1
1979	115,897	109,877	5.2
1980	133,668	133,724	0.1
Average 1971-80			4.7

except for the years 1971 and 1972.* This fact indicates that a reasonable amount of confidence may be placed in the model's forecasts of the near future.

D. SUMMARY

This chapter features a static model of the aluminum demand in Taiwan designed to examine the price change during a supply restriction. The reason for adopting a static model instead of a dynamic model is that the former may be more appropriate to reflect the effect of price change on demand and more consistent with the assumptions of an I-O model, because neither the short-run nor the long-run elasticity may properly forecast the effect of an abnormal supply restriction and the input level in the basic I-O model is only dependent on the output level. Besides, the lagged consumption variable derived from the adaptive expectation model or the stock adjustment model may not be an important factor during an abnormal supply restriction.**

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*The high percentage errors for 1971 and 1972 may have resulted from the change in the economic structure induced by substantial increases in energy cost after 1973. In other words, this model is better able to estimate aluminum demand after 1973, than before that time.

**The stock adjustment model for aluminum demand in Taiwan was estimated by the author as follows:

$\ln C_t =$	-6.61	$+ 0.33 \ln C_{t-1}$	$+ 1.45 \ln RGDP_t$	$- 0.53 \ln P_t$
s.e.	(2.67)	(0.15)	(0.28)	(0.20)
t	-2.48	2.18	5.12	-2.69

$\bar{R}^2 = 0.98$ $F = 113.68$ $h = 1.62$

From the estimated equation, we find the short-run and long-run price elasticities are -0.53 and -0.79, respectively and the value of Durbin h statistic, which is siginficant at the 5 percent significant level for the two tailed test implies no autocorrelation of the error term (Pindyck and Rubinfeld, 1981).

From the estimation results, we found that the income level is highly significant and has a much larger effect on aluminum demand than the price level. This fact is also prevalent in most developing countries.*

In general, the resulting model has proven to be a valid one. In Chapter V, this model will be used as a basis to evaluate consumer surplus due to a supply restriction. The prediction of price changes induced by a restriction in aluminum supply is also based on this model, in which any change in the quantity of aluminum supply will be treated as an equivalent change in the quantity of domestic demand. In Chapter V and VI, these predicted price changes will be incorporated into a substitution model to analyze the substitution effects.

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*The estimation by the World Bank (1981) shows that the income elasticity of aluminum demand for the developing country is 1.90, and the short-run and long-run price elasticities are -0.09 and -1.04, respectively.

CHAPTER IV

ECONOMETRIC ESTIMATION OF SUBSTITUTABILITY BETWEEN ALUMINUM AND COPPER

A. INTRODUCTION

Whenever a commodity supply restriction is imposed, there are several possible counteractions to reduce the demand for the commodity in order to alleviate the economic impact. Four major alternatives are: technological change in input requirement, substitution between material and capital or labor, price induced conservation, and substitution between materials.

The first adjustment measure is technological change, which reduces a commodity unit input requirement of final output. As indicated in Chapter I, technological change in the aluminum sector would not be possible in the short-run and is not discussed here.

The second is substitution of labor or capital for a commodity input. The substitution among bauxite and other inputs in the U.S. primary aluminum industry has been estimated by Moroney and Trapani (1981). However, this substitution effect in the Taiwan primary aluminum industry is not considered because: (1) Domestic primary aluminum is produced only by Talco, which already has an excess labor force and assets since the Kaoshiung I smelter was shut down. A further increase in labor force or capital to reduce the bauxite requirement is therefore impossible in the near future. (2) The data for estimation of this substitution are unavailable.

The third potential counteraction is price induced conservation. This conservation effect is simply referred to as a price induced income effect, which can be derived from an estimated own price elasticity. Section C and consumer surplus analysis in Chapter V explain this effect.

The last potential counteraction is substitution in an intermediate demand of the commodity. Here it is referred to as a substitution among aluminum and related commodities which are demanded as intermediate inputs in the production of outputs for aluminum using sectors.

The purpose of this chapter is to investigate substitution possibilities, in the absence of technological change, in the intermediate demand for aluminum and to examine the effect of this substitution. The next section will discuss the areas of potential substitution. Section C explains the deterministic model for estimating the substitution possibility. Section D presents the estimation results. Section E will present the effect of this substitution on input coefficients.

B. AREAS OF POTENTIAL SUBSTITUTION

A number of materials, such as plastics, steel, and copper, can potentially be substituted for aluminum,* but only the substitutability between aluminum and copper is examined here. This is because copper is

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*A number of materials can be substituted for aluminum, which include plastics, steel, copper, magnesium, and titanium. Plastics mainly compete with aluminum in packaging and containers; steel, in containers and transport equipments. More detailed discussion can be found in Metal Week's Aluminum Profile of an Industry (1968), and Permanent Subcommittee on Investigations' Materials Shortage in Aluminum (1974).

the closest and strongest competitor for aluminum and can be substituted for aluminum immediately in many areas. In addition, the data for the estimation of the substitution possibilities between aluminum and copper are readily available.

Both aluminum and copper are good electrical and thermal conductors. Although copper is better than aluminum in conductivity, aluminum can deliver twice the conductivity for equal weight. Aluminum's advantage in price has been a significant factor in the penetration of several market areas originally held by copper, such as bare transmission cable, automobile radiators, air conditioner tubing, etc. Aluminum's only disadvantage in the electrical industry is that it requires more volume in terms of electrical performance. This disadvantage also explains why copper is preferred in small electronic devices, while aluminum is used in overhead power transmission wires. Table 4.1 lists some relative properties of aluminum and copper and those potential overlapping markets which are also the potential substitution areas.*

In addition to the major potential substitution in electrical devices and equipment and heat exchanger applications, various miscellaneous areas such as alloying and coating applications and ordnance also provide the potential possibility for substitution between aluminum and copper (National Materials Advisory Board, 1972). However, there is no substitution possibility in some areas because some

*The information summarized here mainly comes from the Metals Week's Aluminum-Profile of an Industry (1968), and the National Materials Advisory Board's Mutual Substitability of Copper and Aluminum (1972.)

Table 4.1

RELATIVE PROPERTIES OF ALUMINUM AND COPPER

	Aluminum	Copper
Specific Gravity	2.70	8.95
lb./cu. in.	0.098	0.323
Relative Conductivity (equal volume basis)	59	100
Approximate price/lb.	81¢ (1980) 57¢ (1981)	99¢ (1980) 79¢ (1981)
Approximate price/cu. in.	8.1¢ (1980) 5.7¢ (1981)	32.1¢ (1980) 25.6¢ (1981)
Potential overlapping markets	wide ranae of markets including transport equipment, housing, packaging and electrical equipment	competes in construction for plumbing, tubing, roofing, gutters; electrical applications such as, transtormers, AC induction motors; building wire and power wire, automative electrical and heat exchangers.
Special properties	diversity of utilization attributed to light weight, corrosion resistance, ease of fabrication, electrical conductivity, resistivity, high strength, coatability, non-magnetic and non-toxic	excellent fatigue resistance and corrosion resistance, high conductivity, resistivity, ability to combine to form alloys offering improved properties.

Sources: Metals Week (1969); National Materials Advisory Board (1972); World Bank (1982).

special properties are required for these applications. For example, copper cannot be substituted for aluminum in containers and packaging in which nonmagnetic and non-toxic properties are necessary. Therefore we may assume that electrical devices and equipment, metallic products, transportation equipment, machinery, and construction are the major sectors in which potential substitution between aluminum and copper inputs exist.

In general, "materials are chosen for specific application on the basis of their ability to perform most successfully for the least possible cost" (Metals Week, 1968). Therefore, given the possibility for substitution, the relative price becomes a significant factor in the decision of actual usage. This phenomenon is specially true for aluminum and copper, because aluminum's steady displacement of copper in many areas is largely attributable to its lower unit price. This fact also justifies our assumption of the substitution possibility between aluminum and copper during an aluminum supply restriction.

C. SPECIFICATION OF THE MODEL

The extent of the substitution between copper and aluminum inputs will depend on the relative cost of the two metals. Basically, whenever the price of one commodity increases, two analytically defined effects will come into play simultaneously. One is the substitution effect, which would cause a reduction in purchases of the commodity in question and increases in purchases of related commodities, if output were held constant. This is shown as a movement from point a to point b in Figure 4.1. This movement changes the input ratio of

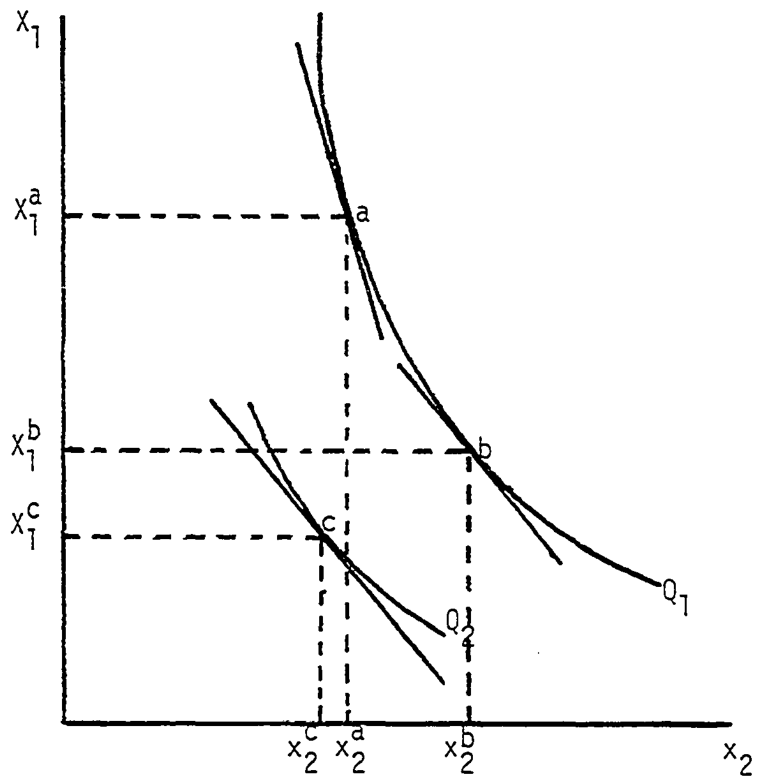

Figure 4.1

THE SUBSTITUTION AND OUTPUT EFFECTS OF AN INCREASE IN THE PRICE OF AN INPUT x_1

the commodities x_1 and x_2. Another effect is the output effect caused by upward shifting of the marginal cost of the output in response to an increase in the price of the commodity input x_1. This shifting would reduce the optimal level of output Q_1 to Q_2 and move production from point b to point c, though at the same relative price level. If we assume that the production function exhibits constant returns to scale, then this movement would not change the input ratio of x_1 and x_2.* However, only the substitution effect is incorporated in the I-O analysis of this study. The reason for excluding the output effect in the modification of input coefficients in the I-O model is that, as mentioned above, the output effect only reduces the sectoral output level and does not change the input structure.

In order to measure the substitution effect in a supply restriction, the elasticity of substitution between aluminum and copper is estimated. Several possible production functions, including the two-level Constant Elasticity of Substitution (CES) production function (Sato, 1967) and the transcendental logarithmic production function (translog) are available for estimation purposes.** Both production functions

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*The definition of constant returns to scale indicates that if the production function is given by $Q = f(x_1, x_2, \ldots, x_n)$, then $f(mx_1, mx_2, mx_3, \ldots, mx_n) = MQ$ where Q is output, x_1 is input, and m is a percentage. This definition says that if we increase output by some percentage m, all the inputs required will be increased by the same percentage m respectively. This fact implies that changing the output level will not change the input ratios.

**A Cobb-Douglas production function is not suitably applied in this estimation because of its rigid assumption of the elasticity of substitution being equal to one.

are sufficiently flexible to be of practical use in empirical estimations. However, the transcendental logarithmic (translog) production function has been the most popular method in the past decade.* The advantage of the translog production function over the two-level CES is that it has flexible functional forms allowing for the estimation of non-restrictive substitution characteristics for the production structure in which multiple products and multiple inputs are included.**

This study employs the two-stage translog production function approach in the manner of Fuss (1977) to estimate the substitution possibility between aluminum and copper inputs. We begin by assuming the existence of an aggregate production function for the whole economy:

$$Q = f(K, L, E, A, C, M) \tag{4.1}$$

where Q is the total gross output (GDP), K, L, E, are aggregate inputs of capital services, labor, and energy respectively, A and C are aluminum and copper inputs; and M is the input aggregate of all other materials. Copper and aluminum are the closest substitute to each other in some areas. Their common properties also somewhat preclude the possibility of substitution markets' overlapping with other materials. Therefore, except for data availability reasons, imposing homotheticaly weak separability in aluminum and copper is not quite

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*The translog production function approach was developed by Christensen, Jorgenson, and Lau (1973). Fuss (1977) expanded it to the two-stage translog production function by imposing homotheticaly weak separability.

**The CES production function assumes that the elasticity of substitution among the inputs is constant.

restrictive. Based on the separability, we can rewrite equation (4.1) as:

$$Q = f(K, L, E, M', M) \quad (4.2)$$

where M' is the aggregate input measure of aluminum and copper.

If we assume that aggregate input prices and total gross output levels are exogenously determined, estimating the cost function instead of the production function will avoid the multicollinearity problem between input levels (Laumas and Williams, 1981).* Given the assumption of cost minimization and using the theory of duality of cost and output levels, the cost function corresponding to the production function (4.2) can be written as:

$$TC = q(P^K, P^L, P^E, P^{M'}, P^M, Q) \quad (4.3)$$

where P^i are price indexes for each aggregator (i = K, L, E, M', and M).** Since $P^{M'}$ is the price per unit of the aggregate input of aluminum and copper, it is also the cost per unit of the aggregate M'. Based on the assumption of homotheticaly weak separability, the general specification of the translog unit cost function for M' therefore may be expressed as follows:***

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*Laumas and Williams point out that the input level is generally endogenously determined, while the input prices are exogenously determined. Therefore, a cost function will avoid the multicollinearity problem caused by the simultaniety.

**The aggregate price index is not a simple weighted average of the price level of the inputs in question, unless these inputs are perfect substitutes or complements (Fuss, 1977).

***For more detailed discussion about the derivation procedure of this two-stage translog cost function, see Fuss (1977), and Hazilla and Kopp (1982).

(4.4) $$\ln P^{M'} = \beta_0 + \Sigma_i\ \beta_i\ \ln P_i + \tfrac{1}{2}\ \Sigma_i\ \Sigma_j\ \beta_{ij}\ \ln P_i\ \ln P_j$$
$$i, j = A, C$$

With the use of Shephard's Lemma and the assumption of cost minimization in M', the optimal derived demand for aluminum and copper can be represented as:

(4.5) $$x_i = \frac{\partial C^{M'}}{\partial P_i} \qquad i = A, C$$

where $C^{M'}$ is the cost of M', x_i is the optimal demand for commodity i. Therefore, relative shares in total cost are:

(4.6) $$S_i = \frac{P_i x_i}{C^{M'}} = \frac{\partial C^{M'}}{\partial P_i} \cdot \frac{P_i}{C^{M'}} = \frac{\partial \ln C^{M'}}{\partial \ln P_i} \qquad i = A, C$$

Given the assumption of cost minization of M', $P^{M'}$ is also equal to the unit cost of M'. To simplify the problem, we assume there is no relationship between aluminum and copper prices. Therefore, estimable share equations can be written as:

(4.7) $$S_i = b_{oi} + \Sigma_j\ b_{ij}\ \ln P_j + e \qquad i, j = A, C$$

where $b_{oi} = \beta_i$, $b_{ij} = \beta_{ij}$, and e is stochastic error. The necessary and sufficient parameter restrictions for the assumption of linear homogeneity in input prices are:

(4.8a) $$\Sigma_i\ b_{oi} = 1$$

(4.8b) $$\Sigma_i\ b_{ij} = \Sigma_j\ b_{ij} = 0$$

(4.8c) $$b_{ij} = b_{ij} \qquad i \neq j$$

From equation (4.7), the constant-output, constant-technology cross-elasticities are therefore calculated as:

(4.9) $$a_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j} \qquad \text{for } i \neq j$$

and the own-elasticities of substitution are:

(4.10) $$a_{ii} = \frac{b_{ii} + S_i^2 - S_i}{S_i^2}$$

The price elasticities of input demand can be calculated as:

(4.11a) $$E_{ij} = S_i \alpha_{ij}$$

(4.11b) $$E_{ii} = S_i \alpha_{ii}$$

According to the stable and cost minimizing input demand principle, E_{ii} must be less than zero.

Because homothetic weak separability is imposed in the production function, these elasticities are equal to net elasticities rather than gross elasticities,* which implies that these elasticities take only the substitution effect into account.** The next section estimates the system (4.7) subject to the parameter restrictions (4.8). The estimated result will provide an estimate of the structure between aluminum and copper inputs.

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*The net elasticity is calculated while holding the output level of the aggregate function constant. The gross elasticity is calculated holding total gross output Q constant. These definitions are prevalent in several text books (e.g. Walter Nicholson, Microeconomic Theory, 1978), but contradicts the definitions by Berndt and Wood. For detailed discussion about the difference between these elasticities, see Berndt and Wood (1979).

**In the present case, only two inputs, aluminum and copper, are assumed in the aggregate input group M'. The cross elasticity of substitution derived from the translog cost function (4) will be equal to the direct elasticity of substitution (Berndt and Wood, 1979).

D. THE ESTIMATION RESULTS

The cost share equations for aluminum and copper are estimated for the whole economy aggregately, because the time series data of the consumption for aluminum and copper on a sector by sector basis are not available.* The data for the cost shares can be calculated as:

$$(4.12) \qquad S_i = \frac{P_i x_i}{\Sigma_i P_i x_i}$$

Because the cost shares always add up to one, the stochastic errors must sum to zero at each observation. This restriction makes the covariance matrix in the system singular. Consequently, we have to delete one share equation from the system. That means we estimate only one of these two share equations in our case, and derive the parameters for another share equation based on the imposed restrictions (4.8). Here we estimate the parameters of the share equation (4.7) using the maximum likelihood (ML) procedure to avoid the potential autocorrelation problem in time series data (Maddala, 1976; p. 283).** The same year period 1971-1980 used in Chapter III is also covered in this estimation. The result of the estimation of the parameters of equation (4.7) is presented as follows:

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*The sources of data for domestic consumption of aluminum and its prices and the data for copper prices have been presented in Chapter III, Section B. For the domestic consumption of copper, we use the source from Metallic Materials in Taiwan, R.O.C. (1980).

**The consequences of autocorrelated errors are that OLS estimators are still unbiased but not efficient. One of the solutions to these problems is to use a modified Cochrane-Orcutt Procedure (one of the maximum likelihood procedures) as developed in Beach and Mackinnon (1978).

(4.13) $S_A = 0.48 + 0.22 \ln P_A - 0.22 \ln P_C$

s.e.	(0.03)	(0.04)	(0.04)
t	17.65	4.91	4.91

$\bar{R}^2 = 0.70$ F = 24.15 DW = 1.86

Based on the value of t ratio, the estimates of all parameters are significant at the 1.0 percent level for a two-tailed test.*

Two issues of primary interest in this study are the elasticity of substitution between aluminum and copper (4.13) and the price elasticity of demand for aluminum and copper. These elasticities can be derived from the estimated equation based on equations (4.9) and (4.11). The estimate of the elasticity of substitution between aluminum and copper is 0.078 (calculated at the mean values of the exogenous variables). This result indicates that copper can substitute for aluminum in the Taiwan industry, but only weakly so. The cross-price elasticities for aluminum and copper are 0.049 and 0.029 respectively. This weak cross-price effect is also reflected in the estimated aluminum model in Chapter III, in which the copper price shows no significant effect on aluminum consumption. The own price elasticities for aluminum and copper are -0.049 and -0.029 respectively. These negative values justify the postulates for stability

*The result of the estimation of the equation S_C can be derived based on equation (4.8). The result is as follows:

$S_C = 0.52 - 0.22 \ln P_A + 0.22 \ln P_C$

s.e.	(0.03)	(0.04)	(0.04)
t	18.82	-4.91	4.91

$\bar{R}^2 = 0.70$ F = 24.15 DW = 1.86

of the demand function.

As mentioned above, these elasticities are net elasticities rather than gross elasticities. Therefore, when we compare the price elasticity for aluminum estimated here with the price elasticity estimated in Chapter III,* we may conclude that the output effects on aluminum consumption in Taiwan may be so great that the substitution effects are overwhelmed by the statistical analysis. This figure may be justified by the fact that Taiwan had very high annual economic and export growth rates in the past decade,** and thus most of the inducement in aluminum demand in Taiwan may be derived from increases in final demand. However, these elasticities will be incorporated in Chapters VI and VIII to modify some of the aluminum input coefficients and to simulate the impact of the substitution effect in an aluminum supply restriction.

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*The price elasticity estimated in Chapter III is a gross elasticity. This elasticity includes the substitution effects and the output effects.

**In the past decade, the average annual growth rate of GDP and exports for Taiwan are 9.7 and 30.8, respectively.

CHAPTER V

METHODOLOGIES FOR ANALYZING SUPPLY RESTRICTION IMPACTS

A. INTRODUCTION

In this chapter, two methodologies for analyzing supply restrictions are presented: consumers' surplus analysis and input-output analysis. An application of these methodologies to aluminum supply restrictions and an interpretation of the results will be presented in the next chapter.

Section B of the chapter presents the consumers' surplus (CS) methodology. This approach relies on demand and supply functions to analyze the welfare loss (consumers' surplus loss) during a supply restriction. For the case of Taiwan's aluminum industry the method is simplified by the presence of a horizontal supply function. Moreover, an examination of the aluminum market structure indicates that a general equilibrium CS analysis is not needed.

The analytical framework of input-output (I-O) analysis is presented in Section C. There are two I-O approaches that can be employed to analyze the impact of a supply restriction: the conventional "demand-driven" I-O model and the "supply-driven" I-O model. Because of inherent limitations in the conventional I-O model, the "supply-driven" I-O model will be used in this study to analyze the impact of an aluminum supply restriction. Since possible biases in input relationships might arise in an application of the supply-driven model, a test for these biases is presented as well.

B. CONSUMERS' SURPLUS ANALYSIS

In general, consumers' surplus (CS) is defined as the difference between total valuation for a specified quantity of the commodity in question (the area under the demand curve) and the market value of that commodity (price times quantity). Graphically it can be represented in Figure 5.1 as the area between the price line and the demand curve. From this figure, it is easy to show that any change in the price level of the commodity will also change consumer surplus. As the price increases, CS will decrease, and vice versa.

CS is a real part of economic welfare.* For a price increase in a given commodity, the consumer would have to give up more income in order to have the same quantity of the commodity. This means he would have to sacrifice the consumption of other commodities and services, hence moving to a lower level of utility. Based on this idea, we can obtain a measure of the magnitude of the reduction in welfare which results from a supply restriction.

Figure 5.2 illustrates the welfare cost of a supply restriction. SS is the domestic supply curve, which reflects the domestic supplier's marginal cost to produce one more unit of a commodity, with the price of inputs held fixed. DD is the demand curve, representing the consumer's marginal valuation of a commodity, with the consumer's income

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*The concept of CS dates back to Alfred Marshall and has gone through several refinements, most notably by Hicks (1941). A great deal of controversy surrounds the appropriate measure of CS. A recent paper by Willig (1976) has helped resolve a good deal of this controversy by showing that "income effect" biases are likely to be small.

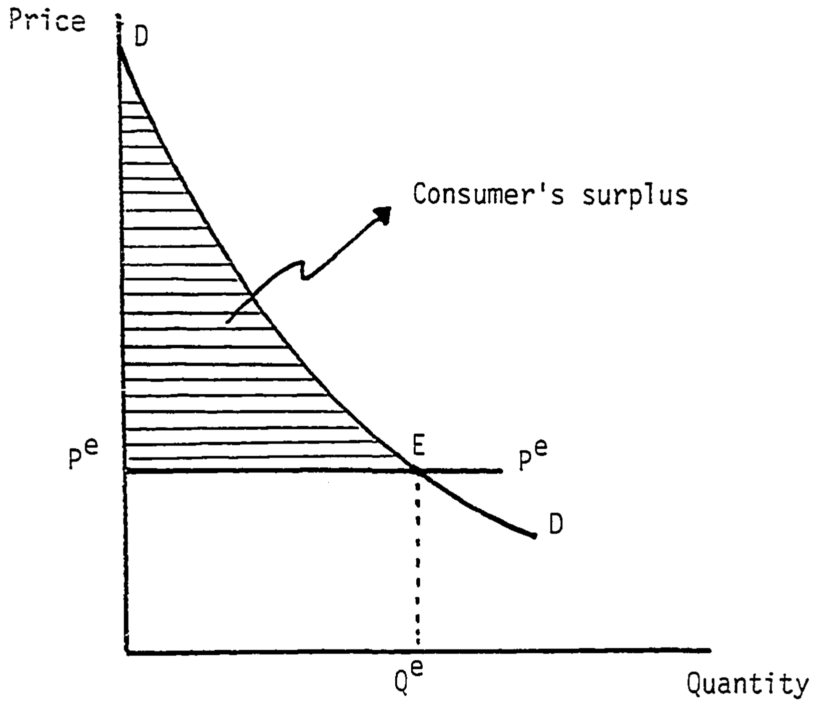

Figure 5.1

CONSUMER'S SURPLUS

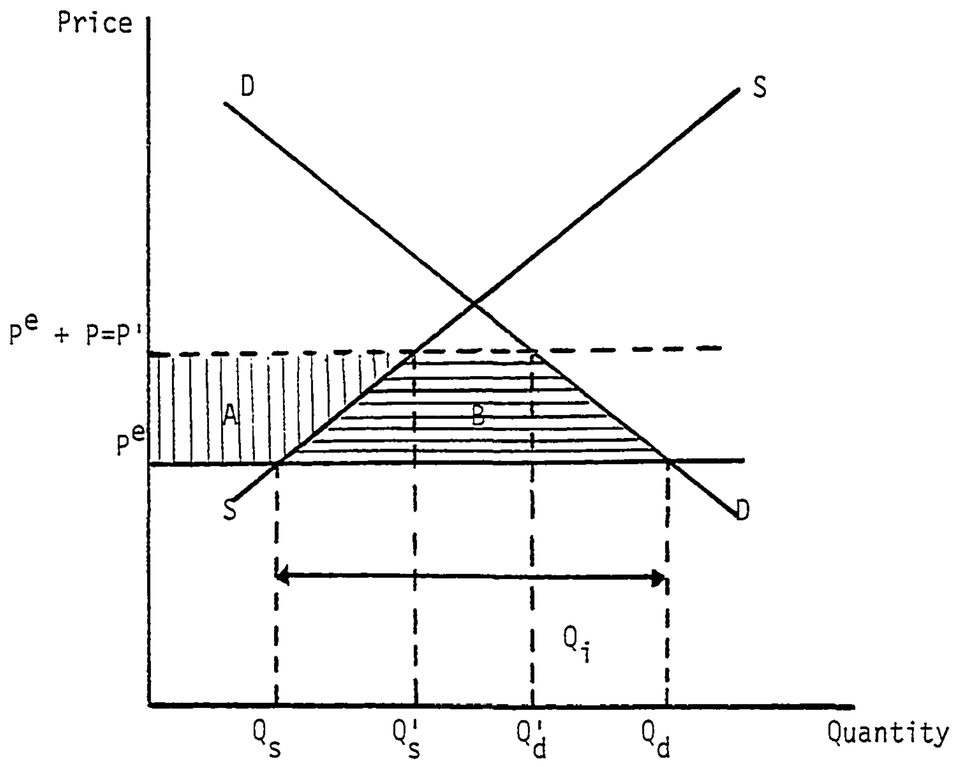

Figure 5.2

WELFARE COST OF A SUPPLY RESTRICTION

and the prices of other commodities assumed to be fixed. P^e represents the constant world price at which imports are available. If a country's imports are very small relative to the total world trade, the world price can be taken as given. Then, based on the given world price, P^e, total domestic supply will be equal to Q_s. Total domestic demand is equal to Q_d. The amount of imports is equal to Q_i (= Q_d - Q_s). Total CS will be the area between the price line (P^e) and the demand curve. Now assume there is a commodity price change, ΔP, induced by a supply restriction. The world price of the commodity increases to P'. The total reduction in consumers' surplus will be equal to the shaded area. The area A in Figure 5.2 is an increase in domestic producers' surplus. It is a transfer payment between domestic producers and consumers; although it is a part of the reduction of consumers' surplus, from the standpoint of the whole economy, it is not a loss. The actual welfare loss for the domestic economy is, therefore, only the area B.

As mentioned in Chapter III, there is no domestic supply curve for aluminum in the case of Taiwan. All aluminum for domestic demand is imported in the form of bauxite, alumina, and aluminum metal. Since the amount imported is very small relative to the total world trade, we can therefore assume that the import total is dependent on the import price and domestic demand. Given the import price and required domestic consumption, total imports are determined. Therefore, if the import price is increased from P^e to P', the total welfare loss will cover the whole shaded area represented in Figure 5.3.

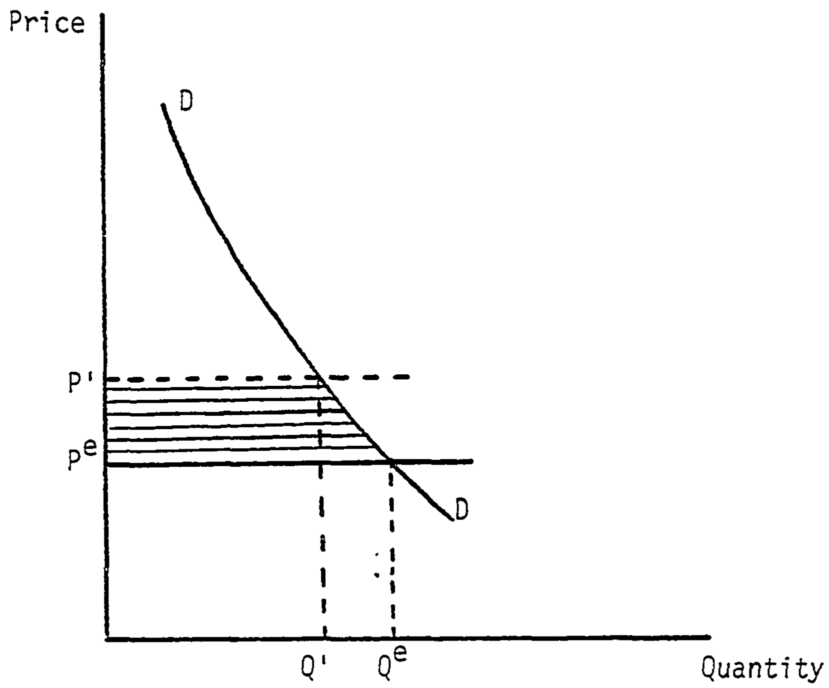

Figure 5.3

WELFARE COST OF A SUPPLY RESTRICTION
WITHOUT THE DOMESTIC SUPPLY CURVE

Figure 5.3 is similar to Figure 5.2, except that there is no conventional supply curve in Figure 5.3.

In general, the welfare loss should be measured within a general equilibrium framework (Carson, 1975). That means a loss in CS would be counterbalanced by increased profits for the supply side. The welfare loss in this study is measured within a partial equilibrium framework rather than a general equilibrium framework, because increased profits on the supply side in the Taiwan aluminum industry are mainly gained by foreign suppliers. Besides, more than 70 percent of the copper, the competitive material to aluminum, used in Taiwan also relies on imports (Chin, 1981). This fact implies that a partial equilibrium analysis would not significantly reduce the accuracy of the results.

Mathematically, the welfare cost can be presented as:

(5.1) $$\text{Total Welfare Loss} = CS_{pe} - CS_{p'} = \int_{p^e}^{P'} f(P)dP$$

where f(P) is a demand function represented by the curve DD in Figure 5.3, in which all influential factors except the price of the commodity in question are assumed fixed; CS_pe is the total CS without a supply restriction, $CS_{p'}$ is the total CS with a supply restriction. The above equation is used to measure the welfare loss of a supply restriction in an aluminum commodity in the next chapter.

C. INPUT-OUTPUT ANALYSIS

This section presents another technique for estimating the amounts of income or output reduction due to a commodity supply restriction. This technique is based on input-output analysis.*

The I-O table describes the demand and supply relationships of an economy for a given period and shows the final demand of goods and services and the interindustry transactions required to meet that demand. The accounting system of an I-O table in an open economy is based on two fundamental identities. One is that the total domestic production of any sector is equal to the sector's products used by all sectors in the economy as an input to produce their output plus the amount demanded for final use by consumers, exports, investment, and government, *minus* total imports of the sector. The second identity is that the total domestic production of any sector is also equal to the total purchases made by the sector from all sectors in the economy plus all returns to primary factors or value added (i.e., wages, salaries, profits, taxes, etc.) in this sector. Based on this double-entry accounting system, the bridge between estimates of the level and composition of GDP** and commodity consumption per unit of sector output for individual sectors can be provided. This bridge is the core of the conventional impact analysis procedure.

A more detailed description of I-O analysis is represented in Appendix B. Here we only discuss the computational procedures in

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*Input-output analysis was developed by Professor Wassily Leontief in the 1920's and 1930's (see, e.g. Leontief, 1941). It's role as a powerful tool of impact analysis is well established in Leontief (1966) and Bulmer-Thomas (1982).

**In general, the total value of gross domestic product (GDP) can be obtained by deducting imports from the total final demand, or by summing up all value added in the I-O table.

I-O analysis. The basic balance equation of I-O (the first fundamental identity) can be represented mathematically as follows:*

(5.2) $$X_i = \Sigma_j x_{ij} + F_i - M_i$$

where X_i = total domestic output of sector i

x_{ij} = purchases by sector j as an input from sector i

F_i = final demand for sector i's product

M_i = total imports of sector i

The intersectoral flows (x_{ij}) and final demand (F_i) contain both imported and domestic product. Total supply or demand of sector i is equal to X_i plus M_i. Assuming the I-O model is a linear intersectoral model of output determination and a fixed-proportion production function for each sector, we can define the direct input or technical coefficients as follows:

(5.3) $$a_{ij} = \frac{x_{ij}}{X_j}$$

where the input coefficient a_{ij} is the amount of inputs directly required from sector i to produce one unit of the output of sector j.

Substituting equation (5.3) into equation (5.2) we obtain:

(5.4a) $$X_i = \Sigma_j a_{ij}X_j + F_i - M_i$$

or

(5.4b) $$X_i + M_i = \Sigma_j a_{ij}X_j + F_i$$

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*If all imports were classified as non-competitive and were included in the primary inputs, then equation (5.2) will be:

$$X_i = \Sigma_j x_{ij} + F_i$$

where all inter-sectoral flows (x_{ij}) and final demand are treated as being of domestic origin and where X_i contains both imported and domestic product.

Based on the above equation and assuming that the ratio of the total import and domestic output for each sector is fixed, then the whole accounting system may be rewritten in an abbreviated matrix form as follows:

$$(5.5) \qquad (I - A + M^d)X = F$$

where A is the direct input coefficient matrix, fundamental to I-O calculation, M^d is a diagonal matrix representing the ratio of the import and domestic output for each sector, and I is the identity matrix. Using this equation and assuming no production technology change in any sector, the vector of domestic output (X) is determined by (given the vector of final demand):

$$(5.6) \qquad X = (I - A + M^d)^{-1} F$$

where $(I\text{-}A\text{+}M^d)^{-1}$ is the inverse of the matrix $(I\text{-}A\text{+}M^d)$, which is similar to the Leontief inverse $(I\text{-}A)^{-1}$ except that the former adds the import ratio vector. The elements of the inverse matrix represents the total interdependence coefficients, which indicate the total direct and indirect requirements by sector per unit of output to final demand. The inverse can be used to determine, for example, the overall impacts of change in expenditure levels of final demand (e.g., increase in government expenditure or investment) or the impacts of change in a sector's domestic output (e.g., plant shutdowns, output reduction, import substitution) on total domestic output and income.

However, this conventional I-O model (demand-driven) focuses on the impacts stemming from final demand, or backward linkage, and output orientation of activities. It may not be appropriate to deal with the impact from primary supply, or forward linkage, and input orientation of activities (Hoover, 1975; pp. 230-232). It is obvious that a supply restriction in our case is a problem of the availability of resources for production. Accordingly, its impact is through the forward linkage and input orientation rather than backward linkage or final demand. Therefore, the conventional impact analysis may not be suitable in our case. Instead, we use the "supply-driven" I-O model to evaluate the impact of a supply restriction in an aluminum commodity.*

The conventional I-O model (based on income and output multipliers) and the "supply-driven" I-O model are symmetrical, but exclusive of each other. The major difference is that the conventional I-O model is dependent on the assumption of fixed input coefficients and a perfectly elastic supply of inputs, but the "supply-driven" I-O model is dependent on the assumption of fixed allocation coefficients and a perfectly elastic demand for a sector's output. This "supply-driven" I-O model, first developed by Ghosh (1958), has been applied to energy issues by Giarratani (1976) and Ayres (1978).

The "supply-driven" I-O model is based on an equilibrium condition of interacting forces through allocation functions rather than

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*In fact, the impact of the price change in a given sector on the price level of all other sectors can be estimated by I-O analysis itself (Leontief, 1966). However, the output effects of unanticipated price changes on the whole economy are unable to be estimated by I-O analysis. One of the ways to evaluate this effect is through macro econometric models (see, e.g., Leiderman, 1979).

through production functions. Based on the second fundamental identity discussed above, the basic balance equation of an I-O table can be represented as follows:

$$X_j = \Sigma_i \, x_{ij} + V_j \qquad (5.7)$$

where V_j is the primary inputs (i.e., labors, capital, etc.), X_j is the domestic output, and x_{ij} is the amount purchased by sector j as input from sector i. We define the allocation coefficient as:

$$d_{ij} = \frac{x_{ij}}{q_i} \qquad (5.8)$$

where q_i is equal to domestic output in sector i plus its imports. d_{ij} indicates direct sales from sector i to sector j per unit total supply of sector i. Substituting equation (5.8) into equation (5.7) yields:

$$X_j = \Sigma_i \, d_{ij}q_i + V_j \qquad (5.9a)$$

or

$$X_j - \Sigma_i \, d_{ij}q_i = V_j \qquad (5.9b)$$

Rewriting the above equation in abbreviated matrix form yields:

$$X - D' \, Q = V \qquad (5.10)$$

$$Q = X + M$$

where Q is a column vector (nx1) of total supply including domestic output (x) and imports (M), X and V are column vectors (nx1) of domestic output and primary inputs respectively, D is the allocation coefficient matrix (nxn) and D' is its transpose. The number of sectors in the economy is indicated by n.

If we also assume that the ratio of imports and domestic output is fixed for each sector, then equation (5.10) can be rewritten as follows:

(5.11) $$X(I - D'(I + M^d)) = V$$

or

(5.12) $$X = (I - D'(I + M^d))^{-1} V = GV$$

where G is the inverse of the matrix $(I-D'(I+M^d))$. Given a change in primary inputs, the impact on domestic output can be determined by the above equation (5.12). The element (g_{ij}) of the inverse matrix G represents changes in domestic output of sector i due to a one unit change in primary inputs of sector j.

In general, fixed allocation coefficients are a weaker assumption than fixed input coefficients. However, Ghosh (1958) has pointed out that under a monopolistic market with scarce resources, the allocation function rather than the production function will play the major role in the economy. An empirical study by Augustinovics (1970) also found that the input coefficient doesn't appear more stable than the allocation coefficient. Therefore, assuming that allocation coefficients are fixed may not be unreasonable during a supply restriction in primary inputs. Based on this assumption, equation (5.12) can be used as a basis to evaluate the impact of a supply restriction on aluminum.

In order to evaluate the impact of aluminum supply restrictions, the aluminum sector is treated as an exogenous sector and put into the primary input group. Consequently, equation (5.12) is changed to:

$$(5.13) \qquad \bar{X} = \bar{G}\ (\bar{V} + \bar{X}_A)$$

where $\bar{X}_A$ is a direct aluminum allocation vector ((n-1)x1). The dimensions of other relevant vectors ($\bar{X}$ and $\bar{V}$) and matrix ($\bar{G}$) are (n-1)x1 and (n-1)x(n-1) respectively (excluding the newly defined exogenous sector--aluminum). The element (a_j) of the vector $\bar{X}_A$ is defined as follows:

$$(5.14) \qquad a_j = \frac{x_{ij}}{\Sigma_j\ x_{ij} + F_i} \qquad i \neq j$$

Based on equation (5.13), the impact of a change in total aluminum supply on domestic output can be estimated as follows:

$$(5.15) \qquad \Delta\bar{X} = \bar{G}\ \Delta\bar{X}_A$$

In the above equation, any reduction in the total supply of aluminum will be proportionally shared by all other sectors because of the assumption of fixed allocation coefficients. Naturally, equation (5.15) can also be used to evaluate the effect of alternative output distribution programs for the sector output. However, it will not be discussed here.

From this "supply-driven" model, we can also estimate the impact of a supply restriction in aluminum on GDP as long as we use the summation of the value added as a proxy for GDP and assume that the ratio of the value added and domestic output for each sector is constant. This estimating equation is represented as follows:

$$(5.16) \qquad \Delta GDP = \bar{V}\ \bar{G}\ \Delta\bar{X}_A$$

where $\bar{V}$ is a row vector (1x(n-1)) of the value added ratio.

Combining equation (5.15) and equation (5.16), the impact of a supply restriction in aluminum on domestic output and GDP can be simulated.

Before proceeding to the next section, some clarification is necessary. First, the substitution among inputs (i.e., changes in input coefficients) implicit in the solution of the "supply-driven" I-O model may be unreasonable. If so, then this model may not be appropriate for analyzing the impact of a supply restriction. The potential problem was tested in the context of the 1979 Taiwan I-O Table as follows: We assumed a 50 percent supply reduction in aluminum in 1979. Then, according to equation (5.13) and (5.15), the new gross output levels will be:

$$\overline{G}\ (\overline{V}_{1979} + \overline{X}_{A,\ 1979} - \Delta\overline{X}_{A}) = \overline{X}_{1979} - \Delta\overline{X} = \overline{X}^{n}$$

where $\overline{X}^{n}$ is the new gross output vector. Based on the new gross output and the original allocation coefficients, we can calculate the new intersectoral flows (i.e., new X_{ij}). The new input coefficients can be therefore obtained by equation (5.3). Results of the test for the aluminum using sectors are shown in Table 5.2. Based on these results, we can conclude that the potentially unreasonable substitution among input in the solution of the "supply-driven" model does not exist in our application.

Second, the impact analysis discussed above is simply based on the existing Taiwan I-O table. It does not include the price-induced conservation effect and substitution effect. This will render the impact analysis biased. The easy way to alleviate it is to estimate the price and substitution elasticities and then incorporate them

Table 5.2

IMPLICIT SUBSTITUTION AMONG INPUTS IN THE SUPPLY-DRIVEN I-O MODEL

CODE1		CODE-16	CODE-16*	CODE-23	CODE-23	CODE-24	CODE-24	CODE-25
01	AGRICULTURE	0.000037	0.000037	0.000000	0.000000	0.000000	0.000000	0.000000
02	LIVESTOCK	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
03	FORESTRY	0.000463	0.000464	0.000091	0.000092	0.000000	0.000000	0.000002
04	FISHERIES	0.000005	0.000005	0.000000	0.000000	0.000000	0.000000	0.000000
05	COAL & COAL PRODUCTS	0.000469	0.000469	0.005937	0.005950	0.003960	0.004052	0.003207
06	CRUDE OIL & NATURAL GAS	0.000442	0.000443	0.000062	0.000062	0.000098	0.000101	0.000240
07	OTHER MINERALS	0.000087	0.000087	0.110533	0.110773	0.000479	0.000490	0.000140
08	MANUFACTURING FOOD	0.000035	0.000035	0.000000	0.000000	0.000017	0.000017	0.000005
09	TEXTILE & APPAREL ACCESSORIES	0.060466	0.060517	0.000260	0.000261	0.002077	0.002126	0.001223
10	WOOD & WOOD PRODUCTS	0.004111	0.004115	0.000244	0.000245	0.005252	0.005377	0.004878
11	PULP PAPER & ALLIED PRODUCTS	0.012200	0.012202	0.001080	0.001082	0.007669	0.007845	0.003056
12	RUBBER & RUBBER PRODUCTS	0.009906	0.009913	0.000248	0.000248	0.000802	0.000820	0.003101
13	PETROCHEMICAL RAW MATERIALS	0.153882	0.153969	0.000030	0.000030	0.000171	0.000175	0.000306
14	OTHER INDUSTRIAL CHEMICALS	0.021785	0.021795	0.000538	0.000539	0.015960	0.016330	0.000917
15	CHEMICAL FERTILIZER	0.001910	0.001911	0.000000	0.000000	0.000002	0.000002	0.000000
16	PLASTICS & PLASTIC PRODUCTS	0.293440	0.293440	0.000538	0.000539	0.007485	0.007655	0.004665
17	MISC CHEMCIAL MANUOFACTURES	0.033871	0.033850	0.002511	0.002514	0.014476	0.014796	0.002661
18	PETROLEUM REFINING PRODUCTS	0.007737	0.007741	0.008244	0.008263	0.005682	0.005814	0.004754
19	CEMENT & CEMENT PRODUCTS	0.000000	0.000000	0.000071	0.000071	0.000117	0.000120	0.000069
20	MISC NON METAL MINERAL PRODS	0.001409	0.001410	0.002773	0.002780	0.002894	0.002963	0.003884
21	STEEL & IRON	0.002016	0.002017	0.074054	0.074198	0.241486	0.247017	0.302268
22	ALUMINUM	0.000824	0.000413	0.001562	0.000784	0.041026	0.021011	0.005446
23	MISC METALS	0.000198	0.000197	0.269429	0.269429	0.070464	0.071938	0.017386
24	METALLIC PRODUCTS	0.010373	0.010143	0.043342	0.042454	0.101386	0.101386	0.033292
25	MACHINERY	0.006087	0.006067	0.010929	0.010912	0.008532	0.008697	0.109015
26	ELECTRICAL APPARATUS & EQUIP	0.001260	0.001250.	0.021298	0.021158	0.002777	0.002817	0.024461
27	TRANSPORT EQUIPMENTS	0.000750	0.000744	0.000503	0.000500	0.001415	0.001436	0.001802
28	MISC MANUFACTURES	0.003867	0.003858	0.000698	0.000698	0.001258	0.001284	0.001738
29	CONSTRUCTION	0.001729	0.001728	0.000268	0.000268	0.001653	0.001689	0.001431
30	ELECTRICITY	0.013678	0.013691	0.011260	0.011291	0.022259	0.022786	0.013967
31	GAS & CITY WATER	0.000365	0.000366	0.000135	0.000135	0.001536	0.001572	0.000424
32	TRANSPORTATION & COMMUNICATIONS	0.012356	0.012365	0.012067	0.012095	0.011921	0.012199	0.013681
33	WHOLESALE & RETAIL TRADE	0.022392	0.022421	0.041723	0.041848	0.035591	0.036445	0.035600
34	MISC SERVICES	0.035786	0.035821	0.060107	0.060290	0.036667	0.037535	0.045536

Table 5.2 (Continued)

CODE		CODE-25	CCDE-26*	CODE-26	CODE-27	CCDE-27	CCDE-29	CCDE-29
01	AGRICULTURE	0.000000	0.000001	0.000001	0.000000	0.000000	0.000370	0.000371
02	LIVESTOCK	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
03	FORESTRY	0.000002	0.000000	0.000000	0.000253	0.000255	0.001528	0.001531
04	FISHERIES	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
05	COAL & COAL PRODUCTS	0.003219	0.000667	0.000673	0.000232	0.000234	0.000000	0.000000
06	CRUDE OIL & NATURAL GAS	0.000241	0.000624	0.000629	0.000000	0.000000	0.000000	0.000000
07	OTHER MINERALS	0.000141	0.000218	0.000220	0.000083	0.000084	0.036893	0.036942
08	MANUFACTURING FOOD	0.000005	0.000015	0.000015	0.000000	0.000000	0.000000	0.000000
09	TEXTILE & APPAREL ACCESSORIES	0.001228	0.002864	0.002890	0.000907	0.000915	0.001192	0.001194
10	WOOD & WOOD PRODUCTS	0.004899	0.008963	0.009046	0.008081	0.008153	0.060429	0.060541
11	PULP PAPER & ALLIED PRODUCTS	0.003067	0.010477	0.010567	0.003489	0.003518	0.001757	0.001759
12	RUBBER & RUBBER PRODUCTS	0.003114	0.002053	0.002879	0.021426	0.021612	0.000638	0.000639
13	PETROCHEMICAL RAW MATERIALS	0.000307	0.000539	0.000543	0.000282	0.000284	0.000000	0.000000
14	OTHER INDUSTRIAL CHEMICALS	0.000921	0.003969	0.004004	0.002656	0.002678	0.000087	0.000087
15	CHEMICAL FERTILIZER	0.000000	0.000038	0.000039	0.000002	0.000002	0.000000	0.000000
16	PLASTICS & PLASTIC PRODUCTS	0.004680	0.039077	0.039403	0.010969	0.011056	0.021879	0.021898
17	MISC CHEMCIAL MANUUFACTURES	0.002668	0.006780	0.006832	0.008165	0.008225	0.010521	0.010524
18	PETROLEUM REFINING PRODUCTS	0.004772	0.003301	0.003330	0.005709	0.005757	0.008051	0.008063
19	CEMENT & CEMENT PRODUCTS	0.000069	0.000000	0.000000	0.000000	0.000000	0.128983	0.129171
20	MISC NON METAL MINERAL PRODS	0.003900	0.010335	0.010431	0.004693	0.004735	0.054958	0.055056
21	STEEL & IRON	0.303338	0.041469	0.041829	0.092000	0.092753	0.115933	0.116061
22	ALUMINUM	0.002737	0.008760	0.004423	0.011117	0.005612	0.001240	0.000622
23	MISC METALS	0.017414	0.021980	0.022125	0.003432	0.003453	0.000186	0.000186
24	METALLIC PRODUCTS	0.032662	0.052535	0.051799	0.024170	0.023822	0.039082	0.038249
25	MACHINERY	0.109015	0.005282	0.005308	0.048272	0.048496	0.003049	0.003041
26	ELECTRICAL APPARATUS & EQUIP	0.024340	0.392184	0.392184	0.013412	0.013407	0.034819	0.034561
27	TRANSPORT EQUIPMENTS	0.001794	0.000634	0.000634	0.282836	0.282836	0.000929	0.000922
28	MISC MANUFACTURES	0.001740	0.003673	0.003696	0.002204	0.002217	0.000851	0.000850
29	CONSTRUCTION	0.001434	0.002161	0.002177	0.001717	0.001729	0.000852	0.000852
30	ELECTRICITY	0.014027	0.008583	0.008663	0.009402	0.009486	0.003043	0.003048
31	GAS & CITY WATER	0.000426	0.001019	0.001029	0.000798	0.000805	0.000611	0.000612
32	TRANSPORTATION & COMMUNICATIONS	0.013736	0.011647	0.011752	0.011593	0.011693	0.032192	0.032241
33	WHOLESALE & RETAIL TRADE	0.035764	0.018505	0.018684	0.049793	0.050255	0.040676	0.040764
34	MISC SERVICES	0.045731	0.048082	0.048529	0.050404	0.050855	0.033486	0.033548

*The second column of each pair is resulted from a 50 percent aluminum supply reduction.

into I-O analysis, which will be presented in Chapter VI.

Third, neither the conventional I-O model nor the "supply-driven" I-O model can handle the production function and the allocation function simultaneously. Therefore, the conventional I-O model or the "supply-driven" I-O model is only able to give us a relatively impressionistic result. The best way to handle this problem is to extend I-O to a linear programming (or more general activity analysis) framework.

D. SUMMARY

In the past decade, consumers' surplus analysis and I-O analysis have been the most popular methods for analyzing the impacts of a supply restriction. A priori, it is difficult to tell which method is better. Consumers' surplus analysis, which is based on econometric supply and demand models, only gives us an aggregate conclusion,* but it can properly reflect the price effect and income effect. I-O analysis can give us the detailed effect on each sector rather than an aggregate effect, but the rigid assumption of a fixed-proportions production function or a fixed allocation function will lead to some bias in our results. This bias can be alleviated by advancing to a dynamic model, e.g., modifying aluminum input ratios according to estimated elasticities of substitution. We will discuss this in

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*Another significant problem associated with consumers' surplus analysis is in the estimation of the supply and demand models. Any bias in the estimation of these supply and demand models will affect the analytical results.

detail in Section D in Chapter VI.

From the discussion presented above, we know how a supply restriction is related to the effected industry and the whole economy. The next chapter will present an application of the methodologies to assessing the impact of an aluminum supply restriction.

CHAPTER VI

THE ECONOMIC IMPACT OF ALUMINUM SUPPLY RESTRICTIONS

A. INTRODUCTION

The purpose of this chapter is to assess the economic impacts of supply restrictions on the Taiwan aluminum industry. Two sets of supply restriction phenomena are presented. The first set focuses on a bauxite cartel action. Results are presented for two hypothetical reduction levels of 3 and 5 percent that are simulated for 1984. The 3 percent level reduction corresponds to a certain critical price level at which alternatives to bauxite become economical. The 5 percent level pertains to a bauxite cartel action under which no available alternatives is assumed and the real price for bauxite is doubled. The second set of more general supply restrictions (embargoes, wars, etc.) refers to reduction levels ranging from 10 to 70 percent in increments of 10 percent. Results are presented for two subcases: the impact of alternative aluminum supply restrictions with the substitution effect and without the substitution effect.

In this chapter, impacts are estimated for each phenomenon by the two analytical approaches presented in Chapter V. The aluminum demand model estimated in Chapter III is used as the empirical basis for the consumers' surplus analysis. The Taiwan I-O table presented in Appendix B is used as the empirical basis of the I-O analysis. Another important approach (the LP model) will be presented in the next two chapters. An overview of the application of these three approaches is briefly shown in Table 6.1. Basically, the consumers'

Table 6.1

AN OVERVIEW OF THE ANALYSIS OF SUPPLY RESTRICTIONS

Consumers' Surplus Analysis	I-O Analysis Without Substitution	I-O Analysis With Substitution	LP Analysis Without Substitution	LP Analysis With Substitution
1. Based on the demand model	1. Based on the "supply-driven" I-O model	1. "	1. Based on the production function	1. "
2. Includes output and price effects	2. No price effect	2. "	2. Input coefficients are fixed	2. "
3. The substitution effect is implicitly incorporated	3. Includes direct and indirect output effect	3. "	3. No price effect	3. "
	4. Allocation coefficients are fixed	4. "	4. Includes direct and indirect output effect	4. "
		5. Includes the substitution effect	5. Includes the economic constraints	5. "
				6. Includes the substitution effect
GDP losses shown in Table 6.2	GDP loss is shown in Table 6.3	GDP loss is shown in Table 6.4	GDP losses shown in Table 8.1	GDP losses shown in Table 8.1

surplus analysis includes the price and output effects of a supply restriction, in which the substitution effect is implicitly incorporated. The I-O analysis with or without the substitution effect only considers the output effect, but this output effect includes the direct and indirect effect through the economy. The LP approach is basically an optimal adjustment approach, based on the production function. No price effect is included, but major economic constraints are incorporated.

The price level during aluminum supply restrictions are determined by equating the remaining available aluminum supply with domestic demand. Because there are some alternatives for aluminum,* the change in the aluminum price level in a cartel action with alternatives is therefore determined as follows:

$$(6.1) \qquad P'_a = P^e_a \, (0.916 + 0.084 \, (\frac{P^c_b}{P^e_b}))$$

where P'_a = aluminum price during a bauxite cartel action

P^e_a = predicted aluminum price without a cartel action

P^e_b = predicted bauxite price without a cartel action

P^c_b = critical price for a bauxite cartel action

Based on the study by Pindyck (1977), the critical price for a bauxite cartel action, at which alternatives to bauxite become economical, is US$59.83 per metric ton in 1980.**

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*Those alternatives include high aluminum clay, anorthosite, nepheline, and syenite. For detailed discussion, see S. Patterson (1977).

**The original critical price was US$39.19 per metricton in 1976 dollar levels, in which the price of natural gas is assumed US$2.20

If we convert the price into NT$ at constant 1979 levels, the critical price will be NR$1,774.96 per metric ton. This critical price will be used in the above equation. The predicted prices for aluminum and bauxite (P_a^e and P_b^e) are based on the research by the World Bank (1982).* The number 0.084 is the cost share of bauxite in total aluminum production costs discussed in Chapter II.

GDP in 1984 is assumed to be NR$1,560,342 million, an 11.10 percent increase from 1982 to 1984. This predicted GDP is derived from the optimal solution in Chapter VIII in order to compare these simulation results among these analytical approaches.

B. ANALYTICAL RESULTS OF CONSUMERS' SURPLUS ANALYSIS

Before presenting the consumer surplus results a complication we should mention that relates to domestic aluminum production. The production cost of aluminum by Talco is higher than the world aluminum market price. We pointed out in Chapter II that Talco has been forced to reduce the charge for its aluminum ignot in order to compete with imports; hence, we can assume that Talco's aluminum price in 1984 will remain at the same level as the price for imported aluminum. However, the difference between the list price of Talco and its production cost, which is subsidized by the government, cannot be treated as a part of

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per MMBTU. It is updated to properly reflect 1980 current price based on the World Bank's report (1982). Because the production of aluminum from alternatives is much more energy-intensive than its production from bauxite, therefore any change in the assuming energy price will have significant effects on the critical price.

*The aluminum price is US$1,980 in 1984 (in current price) and the bauxite price is US$42.5.

consumers' surplus. In a partial equilibrium context, is a loss to the whole economy. Therefore, the total consumers' surplus without a supply restriction will become the area between the price line and the demand curve, as shown in Figure 5.1, minus the total government subsidies for Talco.* Based on these assumptions, the total welfare cost of a supply restriction becomes:

$$\text{(5.2)} \qquad \text{Total Welfare Cost} = CS_{p^e} - CS_{p'} - GS = \int_{p^e}^{p'} f(P)dP - GS$$

where GS represents the total subsidies from the government.

The impacts estimated by consumers' surplus analysis are presented in terms of prices and consumption changes, and consumers' surplus losses, which are listed in Table 6.2. For the subset of cartel actions, the results indicate that the real price level for aluminum increases only 4.0 percent for the case of the critical price constraint (3 percent reduction) and 8.4 percent for the case of a doubling of the baseline bauxite price (5 percent reduction) over the predicted baseline price. The consumers' surplus losses are

*The tariff imposed by the Taiwan government is another factor affecting the measure of consumers' surplus loss because part of the effect of the tariff policy is a "dead-weight" loss to the whole economy. That means the amount collected by government from the tariff may not equal the total cost to the aluminum users. This factor should be considered in future consumers' surplus analysis of aluminum in Taiwan.

Table 6.2

IMPACT OF ALTERNATIVE ALUMINUM SUPPLY RESTRICTIONS UNDER THE CONSUMERS' SURPLUS MODEL
(1979 constant NT dollar)

Supply Condition (percent reduction)	Aluminum Real Price (thousand NTS/MT)	Total Aluminum Consumption (MT)	Consumers' Surpluss Loss (billion NT$)	Consumers' Surplus Loss (percent of GDP)
Baseline[a]	57.5	203,748	---	---
Cartel Action				
3[b]	59.8	198,659	0.03	*[d]
5[c]	62.4	193,498	0.52	*
Supply Reduction				
10	67.8	183,373	1.55	0.1
20	81.5	162,998	3.92	0.3
30	100.4	142,624	6.80	0.5
40	127.8	122,249	10.41	0.7
50	169.9	101,874	15.10	1.0
60	240.8	81,499	21.53	1.4
70	377.4	61,124	31.11	2.0

[a]Baseline refers to the market situation without a supply restriction.
[b]3 percent reduction refers to a bauxite cartel action with a critical price constraint.
[c]5 percent reduction refers to a bauxite cartel action in which the bauxite price is doubled.
[d]less than 0.05 percent.

NT$0.47 billion and NT$0.96 billion, which account for less than 0.1 percent of real GDP in 1984. In the cases of supply disruptions, the aluminum price levels would increase substantially from 17.9 percent for a 10 percent reduction in aluminum supply to more than 600 percent for a 70 percent reduction in aluminum supply. The consumers' surplus losses in supply disruptions range from NT$1.99 billion (0.1 percent of real GDP) to NT$31.55 billion (2.0 percent of real GDP). The results indicate that a bauxite cartel action would not impose nearly as much impact on the Taiwan economy as an aluminum supply disruption. However, from a consumers' surplus standpoint even the largest impact is a relatively small percentage of GDP.

C. ANALYTICAL RESULTS OF INPUT-OUTPUT ANALYSIS

In the I-O analysis, the level of aluminum input for each sector is adjusted in response to a reduction in direct aluminum availability. This adjustment causes reduction of output levels in sectors demanding the aluminum input. The "supply-driven" model presented in the last chapter defined the total impact of a supply reduction on the whole economy through this change of adjustments.

We use the aluminum demand model, as we did in the consumers' surplus analysis, as the baseline for the "supply-driven" model. Aluminum allocation coefficients for each sector are assumed constant. Note, however, that the simple I-O analysis itself can evaluate only the impact of a supply restriction through the input reduction, not through price changes.*

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*In fact, the impact of the price change in a sector on the price levels of all other sectors can be estimated by the I-O analysis

The results of I-O analysis, which are listed in Table 6.3, are presented in terms of supply reduction, changes in domestic output, and losses in real GDP. The reduction of total domestic output ranges from NT$0.94 billion to NT$26.37 billion depending on the percentage of supply reductions. The changes in real GDP range from NT$0.32 billion to NT$9.07 billion. Losses range from less than 0.1 percent to 0.6 percent of our predicted real GDP of NT$1,560 billion. From this table, we also find the levels of reductions of real GDP and total domestic output in the I-O analysis are in proportion to the percentage of supply reductions. It fails to show that more serious supply disruptions are likely to have disproportionate impacts on the whole economy. This is a major inherent limitation in the I-O impact analysis. The next section will incorporate the substitution effect into the I-O analysis in order to analyze the impact of the substitution effect on the analytical results.

D. INPUT-OUTPUT ANALYSIS WITH THE SUBSTITUTION EFFECT

This section examines the impact of the substitution effect between aluminum and copper on the I-O analysis for an aluminum supply restriction. The elasticity of substitution between aluminum and copper estimated in Chapter IV is used as the empirical basis in this section.

(Ayres, 1978). However, the output effects of unanticipated price changes on the whole economy are unable to be estimated by the I-O analysis itself. One of the ways to evaluate this effect is through macro econometric models (Leiderman, 1979).

Table 6.3

IMPACT OF ALTERNATIVE ALUMINUM SUPPLY RESTRICTIONS UNDER THE I-O MODEL
(1979 constant NT dollar)

Supply Condition (percent reduction)	Aluminum Real Price (thousand NT$/MT)	Total Aluminum Consumption (MT)	Output Loss Output Loss (billion NT$)	GDP Loss GDP Loss (billion NT$)	GDP Loss GDP Loss (percent of GDP)
Baseline[a]	57.5	203,748	--	--	--
Cartel Action					
3[b]	59.8	198,659	0.94	0.32	*[d]
5[c]	62.4	193,498	1.89	0.65	*
Supply Reduction					
10	67.8	183,373	3.77	1.30	0.1
20	81.5	162,998	7.53	2.60	0.2
30	100.4	142,624	11.30	3.90	0.3
40	127.8	122,249	15.07	5.20	0.3
50	169.9	101,874	18.83	6.49	0.4
60	240.8	81,499	22.60	7.79	0.5
70	377.4	61,124	26.37	9.07	0.6

[a] Baseline refers to the market situation without a supply restriction.
[b] 3 percent reduction refers to a bauxite cartel action with a critical price constraint.
[c] 5 percent reduction refers to a bauxite cartel action in which the bauxite price is doubled.
[d] less than 0.05 percent.

According to the cost minimization theory of input use, we may write the constant-output demand for aluminum, $\dot{x}_A$, as follows:*

(6.2) $$x_A = g(P_A, P_C)$$

Differentiation of equation (6.1) with respect to time, yields:

(6.3) $$\frac{\partial x_A}{t} = \dot{x}_A = \frac{\partial x_A}{\partial P_A} \frac{\partial P_A}{\partial t} + \frac{\partial x_A}{\partial P_C} \frac{\partial P_C}{\partial t}$$

dividing both side of equation (6.3) by x_A and substituting E_{AA} and E_{AC} for $\frac{\partial x_A}{x_A} \frac{\partial P_A}{\partial P_A}$ and $\frac{\partial X_A}{X_A} \frac{P_C}{\partial P_C}$, respectively, then yields:

(6.4) $$\frac{\dot{X}_A}{X_A} = E_{AA} \frac{\dot{P}_A}{P_A} + E_{AC} \frac{\dot{P}_C}{P_C}$$

The change in aluminum input demand is therefore expressed in terms of its own-price and cross-price elasticities, and relative variations in aluminum and copper prices. To simplify the problem, we assume no change in copper prices during aluminum supply restrictions. Equation (6.4) is then simplified to:

(6.5) $$\frac{\dot{x}_A}{x_A} = E_{AA} \frac{\dot{P}_A}{P_A}$$

Given the price elasticities estimated in Chapter IV and the variation in aluminum price estimated in the previous section, the change of aluminum input demand can be obtained.

As mentioned above, we assume the potential substitution between aluminum and copper only exists in metallic products, electrical

*The optimal demand for aluminum is along an isoquant in the subset M' shown in Chapter IV, in which only aluminum and copper inputs is included in this subset.

apparatus and equipment, transportation equipment, machinery, and the construction sectors. Subject to data problems, the elasticities of substitution are estimated for the whole economy rather than for each sector. Thus, the change of aluminum input demand only happens in these five sectors and the percentage change of aluminum input demand for these sectors is exactly the same.

This information can be incorporated into I-O analysis by the following equations:*

(6.6) $\Delta\overline{X} = \overline{G}\ \Delta X_A\ S$

(6.7) $\Delta GDP = \overline{V}\ \overline{G}\ \Delta X_A\ S$

where S is a row vector (1x(n-1)), with its elements corresponding to those five sectors defined as one minus the percentage change of aluminum input demand estimated by equation (6.5) and the rest of the elements defined as one. Based on these two equations, the impact of an aluminum supply restriction subject to the substitution effect can be evaluated.

However, if there is a minimum aluminum input requirement for a given sectors, then the potential problem of infeasible substitution may emerge.** One way to assess the possibility of an infeasible substitution is to determine the minimal aluminum input coefficient

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*As defined in Chapter V, $\overline{G}$ is the inverse matrix of the matrix $(I-D'(I+M^d))$ in which only 33 sectors are included, $\overline{V}$ is the value added coefficient vector, and ΔX_A is changes in aluminum supply.

**That is, our elasticity measures are constant and calculated for some middle range of an isoquant. There is a limit to how far an elasticity can be extended to reflect extreme input combinations at the ends of the isoquant.

for each sector. Unfortunately, data for constructing these coefficients are unavaible. However, including only five sectors in our analysis, combined with the relatively small elasticity of substitution between aluminum and copper, alleviate the problem.

The results of the simulation are listed in Table 6.4. The reader should note that the first set of columns repeats the results from Table 6.3 for the purpose of comparison. From this table, we find that incorporating the substitution effect significantly reduces the impact on the whole economy during a serious supply disruption. For example, incorporating the substitution effect in a 60 percent supply reduction leads to the real GDP loss NT$6.665 billion, which is only 85.5 percent of GDP loss estimated in the last section (without the substitution effect). For a 70 percent supply reduction, the real GDP loss is only NT$6.790 billion, 74.7 percent of the previously estimated real GDP loss without the substitution effect. This fact implies that an impact analysis which omits the substitution effect would over estimate the economic loss.

E. COMPARISON AND INTERPRETATION OF THE RESULTS

In the previous sections, the impacts of aluminum supply restrictions have been analyzed by the consumers' surplus approach and the I-O model individually. In the I-O model, two subcases have been simulated: an aluminum supply restriction without and with the substitution effect.

Table 6.4

IMPACT OF ALTERNATIVE ALUMINUM SUPPLY RESTRICTIONS UNDER THE I-O MODEL WITH SUBSTITUTION
(1979 constant NT dollars)

Supply Reduction (percent)	$\frac{\dot{P}_A}{P_A}$	$\frac{\dot{X}_A}{X_A}$	No Substitution		With Substitution		Substitution Offset	
			GDP Loss (billion NT$)	Output Loss (billion NT$)	GDP Loss (billion NT$)	Output Loss (billion NT$)	GDP Offset (billion NT$)	Output Offset (billion NT$)
3	0.040	0.002	0.324	0.939	0.323	0.938	0.001	0.001
5	0.084	0.004	0.653	1.892	0.651	1.886	0.002	0.005
10	0.179	0.009	1.299	3.760	1.288	3.737	0.011	0.023
20	0.419	0.020	2.598	7.520	2.549	7.414	0.048	0.106
30	0.746	0.037	3.896	11.280	3.763	10.988	0.134	0.292
40	1.221	0.060	5.195	15.040	4.906	14.405	0.289	0.634
50	1.954	0.096	6.494	18.800	5.916	17.534	0.578	1.266
60	3.186	0.156	7.793	22.560	6.665	20.094	1.128	2.466
70	5.561	0.273	9.092	26.320	6.790	21.274	2.301	5.045

From these results, we find that the losses of GDP in the I-O model are less than the losses in the consumers' surplus analysis, especially during the serious supply restrictions. For example, the consumers' surplus losses for 50 percent and 70 percent reductions in aluminum supply are NT$15.54 billion and NT$31.55 billion respectively. But, based on the I-O model, these losses are only NT$6.49 billion and NT$9.07 billion. One of the reasons for the difference between results in these two analytical approaches is that the I-O model does not include output effects of unanticipated changes in aluminum input prices. The I-O model only takes account of the output effect of material balance constraints. However, the different analytical bases of these methods may be another reason for the difference.

Another important distinction among these results is that incorporating the substitution effect has a significant effect on the I-O analytical results during a cut in aluminum supply above 50 percent. For example, the GDP loss for a 30 percent reduction without the substitution effect is NT$3.90 billion. For the case of incorporating the substitution effect, the GDP loss is NT$3.76 billion. The GDP offset is only NT$0.14. But for a 70 percent reduction, the GDP offset jumps to NT$2.30 billion. This fact is also reflected in our optimal adjustment model in Chapter VIII.

Conceptually, the impacts of supply restrictions should be discontinuous. In other words, above some level of supply restrictions, the impact should be extremely higher than that in a mild supply restriction. However, neither the consumers' surplus approach nor the

I-O model can really reflect this characteristic. This fact constitutes one of the reasons to inspire us to further develop the LP model to analyze the impact of a supply restriction. We will present the LP model in detail in the next chapter.

CHAPTER VII

METHODOLOGIES FOR PLANNING THE OPTIMAL ADJUSTMENTS TO SUPPLY RESTRICTIONS: THE LINEAR PROGRAMMING MODEL

A. INTRODUCTION

In Chapter V, the impact of a restriction in aluminum supply on the whole economy was evaluated based on consumers' surplus analysis and input-output analysis. These models have several inherent limitations mentioned earlier. Also, while they present an indication of the impacts of a supply restriction in the absence of adjustment policies, they fail to provide the details of an optimal response. The work of the policy-maker is to understand the sensitivity of each sector in the economy to an exogenously determined supply restriction, and then to devise practical policies that will reduce the joint economic costs of the impacts and the adjustment policies.

Of all the formal techniques for impact analysis, the linear programming approach may be the most detailed and powerful. This is partly because it can provide a general equilibrium framework for examining resource allocation and partly because it can be used to determine the optimal sectoral adjustment pattern for any specified objective function.

The purposes of the following two chapters are to demonstrate the usefulness of an LP model of national economic activity for identifying each sector's optimal response to a critical mineral supply disruption and to depict the applicable adjustment patterns of the economy to this impact based on the policy-maker's economic objective. These purposes are mainly inspired by the growing concern for an optimal resource allocation strategy during a resource supply restriction. The causes for this concern are that the resource allocation strategy may play a very important role in adjusting the economy to a supply restriction and may be determined exogenously by the policy-maker. Therefore, the main emphasis of the framework presented here is not only on what is the optimal output response of each sector, but also on what is the optimal restricted resource allocation strategy for the policy-maker.

Basically, LP transforms I-0 into an optimization model framework. The LP version retains the assumption of a fixed proportional production function, but incorporates macro constraints, domestic scarce resource constraints, and primary input constraints. Other differences between the I-0 and LP models is that the latter allows for joint products, alternative production technologies and unused resources.*

The LP technique is valuable to the policy-maker in that it can clearly reveal the relation between the optimal responses of a sector's production and the use of the restricted mineral resource and show the criteria for the allocation of the restricted resource. The allocation criterion is a matter of choice as to which sectors should be given priority for allocation of the restricted resource.

A detailed description of the LP model and its distinctive features are presented in Section B of this chapter. A discussion of

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*For detailed discusssion about the difference between the I-0 and LP models, see Dorfman, et al., (1958), Chapters 9 and 10.

analytical results of the model are presented in Chapter VIII.

B. DESCRIPTION OF THE LINEAR PROGRAMMING MODEL

The major purpose of the LP model developed here is not to search for an optimal development planning pattern (e.g., Bruno, 1970; and Manne, 1974), but to simply explore the impact of a supply disruption and identify the optimal responses of sectors under alternative commodity supply assumptions. Hence, the main objective of this model is to predict the optimal adjustment pattern for each sector. However, a significant change in the output structure of the whole economy would require large-scale and drastic government intervention. This is not a feasible short-run policy. Therefore, analytical satisfaction and practical feasibility become the main emphasis in this model.* In other words, the model is designed to allow changes in the output structure to occur smoothly and in a practical manner rather than allow large changes, which are less realistic, to occur all at once.

A thirty-four sector optimal adjustment model is presented below. Since the study is focused on short-run phenomena, the model is static instead of dynamic.** Optimal adjustment programs are obtained by maximizing GDP in the year that a supply disruption occurs. This objective function (Maximizing GDP) is prevalent in governmental development planning in Taiwan (Lee, 1980).*** The model incorporates a

*Practical feasibility will likely cause a divergence from the theoretical optimal solution. This also entails some cost from the normative economic point of view. However, practical applicability is the first priority of policy-makers.

**The model builds on the work of Bruno (1970) and Golladay and Sandoval (1972).

***Some other objective functions could be made, such as: maximizing consumption or maximizing total gross output.

hierarchy of constraints. These include limitations on the balance of payments, domestic resources, private consumption and export activities. The constraints are set initially to reflect normal (baseline) conditions. Constraints are then revised because they are overly restrictive when serious disruptions are assumed. Levels of a sectoral domestic output and total final demand are the main variables for which optimal adjustment values for the supply disruption period are investigated.

The model is presented in detail in Table 7.1. The symbols of the primal variables and parameters, and their definitions are listed in Table 7.2 and 7.3. The subscripts i or j run from 1 to 34 and denote economic sectors.

A sector's output balance constraints (7.1) indicate the minimum private consumption requirements for the output of the thirty-four sectors. It is based on I-O relations of the Leontief type. The input-output coefficients (a_{ij}) are mainly derived from the 1979 Taiwan I-O table. No technological change between 1979 and 1984 is assumed. Although the assumption of the fixed proportional production function remains, the predicted substitution effect in Chapter IV will be taken into account for the inputs of aluminum and copper ($a_{22,j}$ and $a_{23,j}$) during the imposed supply disruptions. Government and private expenditures and fixed capital formation are taken as exogenously given by simply assuming no less than the amount in the base year. In the 1979 Taiwan I-O table, imports are treated as being competitive and put in a separate column. Thus, the inter-sectoral flows contain both imported and domestic product. In order to

Table 7.1

THE OPTIMAL ADJUSTMENT MODEL

	Constraint	Associated Sectors[a]	Number of Constraints
(7.1)	Sectoral output balance constraints		
	a) $X_i + m_i X_i - \Sigma_j a_{ij} X_j - C_i - E_i \geq \underline{GI}_i$	$i \neq 5, 6, 22$	31
	b) $X_i + m_i - \Sigma_j a_{ij} X_j - C_i - E_i \geq \underline{GI}_i$	$i = 5, 6, 22$	3
(7.2)	Private consumption constraints		
	a) $C_i \geq \underline{C}_i$	$i \neq$ 13-15, 19, 21-23	27
	b) $\Sigma_i C_i \leq 0.5$ GDP		1
(7.3)	Fixed investment constraint		
	$\Sigma_j k_j (X_{j,\,1984} - X_{j,\,1979}) \leq FI - D$		1
(7.4)	Export constraints		
	a) $\underline{E}_i \leq E_i \leq \overline{E}_i$	$i \neq 5, 6, 29, 30, 31$	29
	b) $E_i = 0$	$i \neq 5, 6, 29, 30, 31$	5
(7.5)	Balance of payments constraints		
	$E_i - \Sigma_i m_i X_j - M_5 - M_6 - M_{22} \geq 0$		1
(7.6)	Labor constraints		
	a) $\Sigma_j l_j^s X_j \leq L^s$		1
	b) $\Sigma_j l_j^{ns} X_j \leq L^{ns}$		1

Table 7.1 (Continued)

	Constraint	Associated Sectors[a]	Number of Constraints
(7.7)	Domestic production capacity constraints		
	a) $X_i \leq b_i X_{i,1979}$	$i \neq 5, 6, 22$	31
	b) $X_5 = 1.072 X_{5, 1979}$		1
	c) $X_6 = 1.093 X_{6, 1979}$		1
	d) $X_{22} = X_{22, 1979}$		1
(7.8)	Minimum domestic production constraint		
	$X_i \geq \underline{X}_i$	$i \neq 5, 6, 22$	31
(7.9)	Domestic scarce resource constraints		
	a) $\Sigma_j e_j X_j \leq EL$		1
	b) $\Sigma_j g_j X_j \leq GS$		1
	c) $\Sigma_j f_j X_j \leq FL$		1
	d) $X_{22} + M_{22} \leq S_a$		1
(7.10)	Objective function		
	Maximizing GDP = $\Sigma_j v_j X_j$		1

[a]Without indication, the subscript i or j will run from 1 to 34.

Table 7.2

THE PRIMAL VARIABLES

Notation	Definition	Associated Sectors[a]
X_i	Sectoral domestic gross output	
C_i	Private consumption	$i \neq$ 13-15, 19, 21-23
E_i	Exports	$i \neq$ 5, 6, 29, 30, 31
$\underline{E}_i$	Lower bound on exports	$i \neq$ 5, 6, 29, 30, 31
$\overline{E}_i$	Upper bound on exports	$i \neq$ 5, 6, 29, 30, 31
$\underline{GI}_i$	Minimum level of government expenditure and investment	
M_i	Total imports	i = 5, 6, 22
FI	Fixed investment	
D	Capital depreciation	
L^s	Total supply of skilled labor	
L^{ns}	Total supply of non-skilled labor	
$\overline{X}_i$	Upper bound on domestic capacity	
$\underline{X}_i$	Lower bound on domestic capacity	$i \neq$ 5, 6, 22
EL	Total supply of electricity	
GS	Total supply of gasoline	
FL	Total supply of fuel oil	
S_a	Total aluminum supply	

[a]Without indication, the subscript i will run from 1 to 34.

Table 7.3

THE PRIMAL PARAMETERS

Notation	Definition	Associated Sectors[a]
m_i	Import-domestic output ratios	$i \neq 5, 6, 22$
a_{ij}	Input-output coefficients	
k_j	Capital-output ratios	
l_j^s	Skilled labor-output coefficients	
l_j^{ns}	Non-skilled labor-output coefficients	
b_i	Maximum capacity expansion coefficients	$i \neq 5, 6, 22$
e_j	Electricity-output coefficients	
g_j	Gasoline-output coefficients	
f_j	Fuel oil-output coefficients	
v_j	Value added-output coefficients	

[a]Without indication, the subscript i or j will run from 1 to 34.

determine the proper level of domestic output from the model, we simply assume that the import-domestic output coefficients are always the same as they were in the base year so that the imports can be incorporated in the diagonal elements of the input-output coefficient matrix (Chenery and Clark, 1959; and O'Connor and Henry, 1975).* Then, the level of imports can also be derived from the model. However, this is not a realistic assumption for the coal, oil and natural gas, and aluminum sectors because these sectoral output levels have been strictly limited by their capacities and/or reserves. Therefore, the import-domestic output coefficients for these sectors are directly determined by the model.

The private consumption constraints (7.2) present the minumum limitations for sectoral private consumption and the limitation for the total private consumption. The minimum private consumption on a sector by sector basis is simply taken to be the levels in the base year. The total private consumption is limited by one half of GDP in that year.**

The fixed investment constraint (7.3) expresses the requirement that the total investment in capacity expansion shall not exceed the finance available for this purpose minus the capital depreciation.

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*The advantage of this assumption is that imports are determined endogenously rather than exogenously, simplifying the study. As O'Conner and Henry (1975) and others have noted this assumption is not always realistic, since the import-output coefficients of some sectors may change over time.

**This limitation is taken from the Council for Economic Planning and Development's Ten-Year Economic Development Plan for Taiwan, R.O.C. (1980).

This constraint also implicitly assumes full utilization of capacity in the base year.

Export constraints (7.4) present the limitations for export activities. For most sectors, lower and upper limits are imposed. The lower limits are taken to be the levels in the base year, 1979. This is based on the assumption that an actual decrease in export activity has seldom happened in an open economy, because it would result in excess capacity (Bruno, 1966). The upper limits are estimated from the past performance. For the coal, oil and natural gas, construction, electricity, and gas and city water sectors, no export activities are assumed.

The balance of payments constraint (7.5) simply assumes that the total value of imports must be equal or less than the total value of exports. The net foreign capital commitments and accumulated balance of payment surplus are not included in the constraint, because Taiwan has had a positive trade surplus since 1971 (except in 1973 and 1974). However, this constraint will be removed during the imposed serious supply disruption.

Labor constraints (7.6) are divided into two groups, skilled and unskilled. The sum of labor of each group demanded for domestic output cannot exceed the availability of labor of that group in 1984. The labor-output coefficients of each group have been modified to appropriately reflect the improvements of productivity during the study period.

Sectoral output level constraints (7.7 and 7.8) are set up to preclude the solution of totally infeasible or impractical outputs for a sector. Upper and lower bounds are incorporated. Upper bound constraints (7.7) indicate that domestic output in the ith sector is limited by the projected maximum capacity available in that sector. Lower bound constraints (7.8) for sectoral output levels are taken to be the levels in the base year, which are based on the primary condition that neither private industry nor government will move to decrease output below the level in the base year, resulting in excess capacity.

Domestic scarce resource constraints (7.9) refer to electricity, gasoline, and fuel oil. These constraints are included because energy is a very scarce resource in Taiwan and efficient energy use has been emphasized in governmental policy since 1979.* Including these constraints will properly capture the government's policy. Resource-output coefficients are assumed to be fixed during the period.

Again, the objective function (7.10) is simply to maximize real GDP in 1984. Calculation of GDP in 1984 is based on the value-added coefficients which are derived from the 1979 I-O table. We assume that the value-added component of a one unit increase in a sectoral output has no change from 1979 to 1984. While assumption is not always realistic in the long-run, it may be appropriate in the short-run.

C. DATA COLLECTION

The model developed above is estimated for Taiwan based on published or estimated data. The Taiwan 1979 I-O table compiled by

*In 1980, the imports of energy accounted for 86.4 percent of the total energy demand in Taiwan.

the Overall Planning Department, Executive Yuan is used as its basis. From that table, the input-output coefficients, import-output coefficients, lower bounds for export activities, final demand (government and private expenditures, and fixed capital formation), sectoral output, and value-added coefficients are obtained. The maximum capacity expansion coefficient (b_i) for each sector in 1984 is based on the estimates by the Council for Economic Planning and Development (CEPD) (Lee, 1980). In the five-year period, the maximum capacity expansion coefficients for sectors 1, 2, 3, and 4 are 1.2; for sector 8, 1.3; for sector 9, 1.5; for all other sectors, 2.0. The output levels for the coal and oil and natural gas sectors are predetermined based on the estimates in the CEPD's Ten-Year Economic Development Plan for Taiwan, R.O.C. (1980). From 1980 to 1984, a 7.2 percent increase for the coal sector's output and a 9.3 percent increase for the oil and natural gas sector's output are assumed. For the aluminum sector, the output level in 1984 is assumed to be fixed at the 1979 output level.

The capital-output coefficients, labor-output coefficients, and scarce resource-output coefficients are obtained from the research reported in the CEPD (Lee, 1980). These coefficients are further updated from the 1978 price level to the 1979 price level based on the price index for each sector reported in the Industry of Free China. Labor-output coefficients are moreover modified to be able to reflect the predicted labor productivity level in 1984. Annual capital depreciation is simply assumed to be fixed at the 1979 level. Fixed investment available from 1980 to 1984 is based on the projection by

CEPD (1980). Total supplies of scarce resources, skilled and unskilled labor in 1984 are derived from the total supplies in 1979, in which the annual growth rates from 1979 to 1984 are based on the projection by government (CEPD, 1980).* All money variables are measured in millions of New Taiwan dollars (NT$) at 1979 constant prices and related to the year 1984.** All data required here are listed in Appendix C.

D. SUMMARY

In this chapter, the structure of the LP model and the implications of the constraints have been illustrated with an understanding of how a resource supply disruption is related to decision-making (the objective function) and to both behavioral constraints (e.g., minimum final demand) and nonbehavioral constraints (e.g., supply of primary inputs). Because this model includes the major constraints to the Taiwan economy, the simulation results of a supply restriction would be realistic enough for practical policy-making.

The exogenous and predetermined variables and coefficients in the model are mainly derived from the Chinese government's reports and publications. The resulting model, in the full form, contains 170 constraints and 90 variables. The economy is represented by 31

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*The annual growth rate for skilled and unskilled labor supplies are assumed to be the same as the annual growth rate for total labor supply, which is equal to 2.7 percent.

**Based on the study by Bezdek and Wendling (1976), constant-dollar estimates are generally more accurate than the current-dollar forecasts.

endogenous sectors and 3 exogenous sectors (aluminum, coal, and oil and natural gas). Two labor skills are distinguished in this model: skilled and non-skilled. The model is to be run for the year 1984, each time with a different aluminum supply availability. The analytical procedures and the simulation results will be discussed in the following chapter.

CHAPTER VIII

THE OPTIMAL ADJUSTMENT PATTERN TO AN ALUMINUM SUPPLY RESTRICTION

A. INTRODUCTION

The simulation results of an aluminum supply restriction based on the model of the previous chapter are presented below. The discussion focuses on the optimal adjustment patterns and the optimal aluminum allocation functions. The substitution effect is also incorporated into the simulation. In order to prevent the analytical solutions of the model from being theoretically feasible but practically unfeasible, an iterative solution procedure will be used.

In order to obtain a partically optimal adjustment for aluminum supply restrictions, a four-step procedure is applied:

(1) Examine the consequences of optimal adjustment for a disruption in aluminum supply. If a feasible solution is obtained from the model, it is also an optimal one to policy-makers. However, a feasible solution may not be achieved during a serious supply disruption, because some constraints in the original model may be too rigid. In this case, a modification of the original constraints is necessary.

(2) Release the balance of payments constraint. Releasing the balance of payments constraint first is necessary since it is the strictest one during an aluminum supply disruption. In this step, we also aggregate export activity constraints and private consumption constraints to be total final demand constraints. This aggregation will not make much difference for the solution, but will simplify the

computation.

(3) Adjust minimum final demand constraints for aluminum using sectors. Even though we release the balance of payments constraint, the previous minimum final demand constraints may not be justified during an imposed serious supply disruption. As mentioned above, we do not want to alter the economic output structure dramatically. Therefore, we only reduce the minimum final demand constraints for aluminum using sectors at this step.

(4) Adjust minimum final demand constraints for the rest of the sectors in the economy. If a feasible solution could not be obtained from step 3, then we will further reduce the minimum final demand constraints for the rest of the sectors. In each adjustment in step 3 and step 4, we reduce only the amount of the original minimum final demand constraints by 10 percent. Therefore, any feasible solution obtained from step 3 or step 4 is a practical solution rather than an optimal solution. If no feasible solution was found in this step, the procedure will go back to step 3 to further reduce the minimum final demand constraint and reiterate this computation.

A flow chart of the analytical procedure is shown in Figure 8.1. Note that the substitution effect can also be included in the model. However, for the purpose of analyzing the impact of the substitution effect, the model will first be run without the substitution effect. The model differs from the "supply-driven" model. It is based on the fixed production function and allows the allocation function to be operated in an optimal way. Therefore, the substitution effect

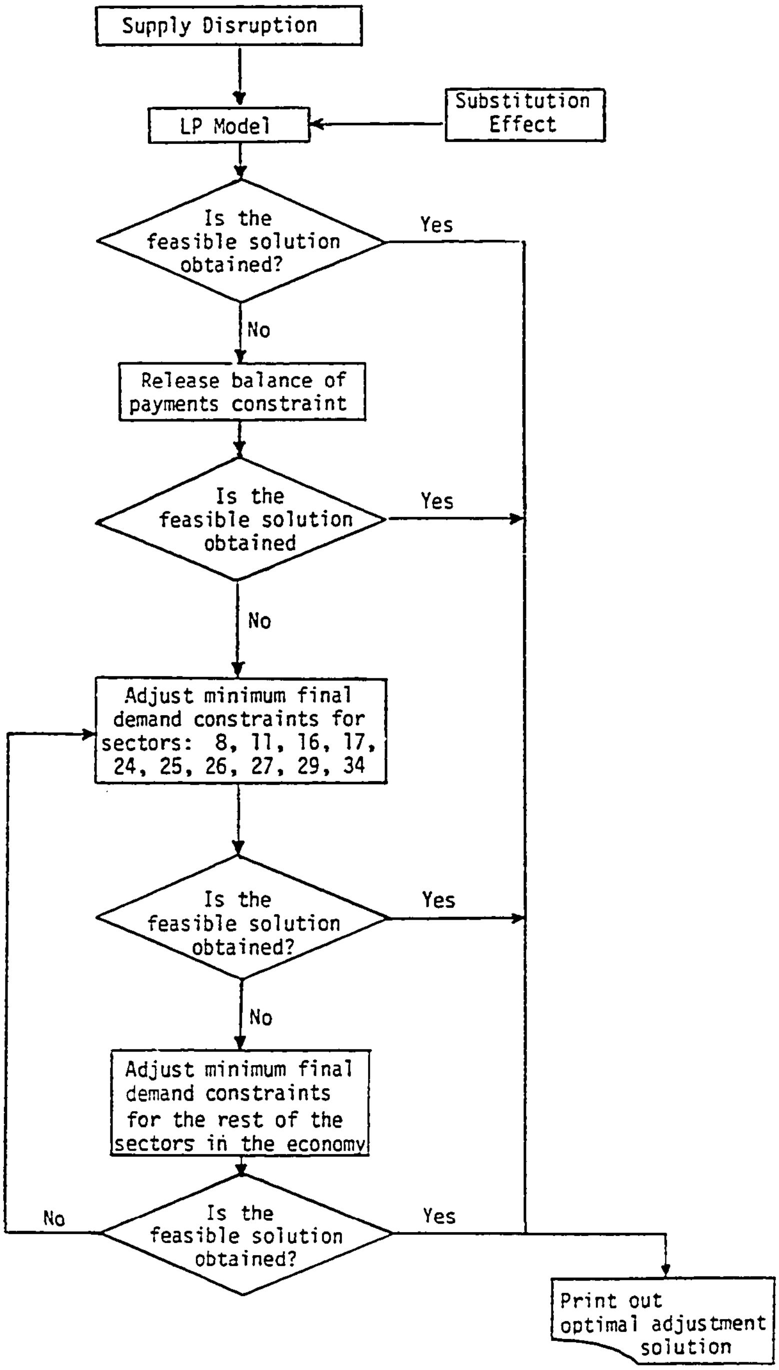

Figure 8.1

COMPUTER ALGORITHM FOR IMPACTS OF SUPPLY RESTRICTIONS is incorporated into the aluminum input coefficient (a_{ij}). The adjustment procedure is as follows:

$$(8.1) \qquad x^n_{ij} = x_{ij} \left(1 - \frac{\dot{x}_{ij}}{x_{ij}}\right)$$

$$(8.2) \qquad a^n_{ij} = \frac{x^n_{ij}}{X_j} = \frac{x_{ij}}{X_j} \left(1 - \frac{\dot{x}_{ij}}{x_{ij}}\right) = a_{ij} \left(1 - \frac{\dot{x}_{ij}}{x_{ij}}\right)$$

where $\dot{x}_{ij}/x_{ij}$ is a percentage change in input demand due to the substitution effect, which has been calculated in Chapter VI, a_{ij} is the original input coefficient and a^n_{ij} is the adjusted input coefficient.

B. THE OPTIMAL ADJUSTMENT PATTERNS: ANALYTICAL RESULTS

This section first presents a basic solution to the model formulated in Chapter VII. Then the optimal solutions of the model are traced by varying the amount of the total aluminum supply and constrasting the results. The four step procedure represented in Section A is used here. The basic solution is obtained from the first step without imposing a restriction in the aluminum supply. However, from the results of the simulation we find that when the percentage of reduction in aluminum supply is more than 40 percent, no feasible solution can be obtained in step 1. This means the balance of payments constraint as well as all of minimum final demand constraints are not attainable after a supply reduction above 40 percent.

Table 8.1 summarizes the impacts of GDP from the results of the simulation. From the basic solution, we find that, at the level of

GDP NT$1,560,342 millions (which is equal to the level of GNP used in Chapter III), the optimal demand for aluminum is only 136,717 tons (NT$12,450 millions) which is 33 percent less than the estimated demand (203,748 tons) in Chapter III. In other words, if aluminum demand in 1984 is assumed to equal the demand that was estimated in Chapter III, then the result of the basic solution implies that as long as the economy operates at the output levels in the basic solution, a supply reduction of less than 33 percent may not cause a loss in the economy. For the convenience of comparison, the level of the supply reduction throughout this chapter corresponds to the estimated aluminum demand in Chapter III. However, the changes of the aluminum supply relative to the optimal demand in the basic solution are presented in parentheses in Table 8.1.

In Table 8.1, a 40 percent reduction in aluminum supply causes only 0.2 percent loss in real GDP. But, a further percentage cut in aluminum supply will shrink GDP dramatically. As a result of a 50 percent reduction, the GDP is reduced by 10.4 percent. Up to a 70 percent reduction, the GDP loss will jump to 44.0 percent. This dramatic change in GDP loss is because most impacts of an aluminum supply reduction below 40 percent are only due to the effect on output of the major aluminum using sectors. Above 40 percent, the impact will be distributed among the whole economy, not only the major aluminum using sectors. This fact is clearly evident in Table 8.2, in which the changes in domestic output levels due to an aluminum supply reduction are presented. The optimal levels of output as taken from the basic

Table 8.1

CHANGES IN REAL GDP DUE TO ALUMINUM SUPPLY RESTRICTIONS[a]

Supply Reduction (percent)	No Substitution Effect			With Substitution Effect		
	GDP (NT millions)	ΔGDP (NT millions)	ΔGDP (percent)	GDP (NT millions)	ΔGDP (NT millions)	ΔGDP (percent)
10	--[b]	--	--	--	--	--
20	--	--	--	--	--	--
30	--	--	--	--	--	--
35 (3)[d]	1,559,288	1,054	0.1	*[c]	*	*
40 (11)	1,556,778	3,564	0.2	1,558,026	2,316	0.1
50 (25)	1,398,623	161,719	10.4	1,555,276	5,066	0.3
60 (40)	1,021,956	538,386	34.5	1,480,446	79,896	5.1
70 (55)	873,449	686,983	44.0	1,240,712	319,630	20.5

[a]The real GDP without a supply restriction is equal to NT $1,560,432 millions in 1984.
[b]"-" represents no change in GDP if the economy is operated according to the optimal adjustments pattern.
[c]"*" represents no substitution effect is incorporated.
[d]The numbers in parentheses represent the percentage of supply reduction corresponding to total aluminum demand in the basic solution, which is equal to 136,717 tons (NT $12,450 millions).

Table 8.2

CHANGES IN DOMESTIC OUTPUT DUE TO ALUMINUM SUPPLY RESTRICTIONS WITHOUT A SUBSTITUTION EFFECT
(NT millions)

Code	Sector	Base Year (1979)	Basic Solution[b]	Percentage Reduction in Aluminum Supply				
				35%	40%	50%	60%	70%
1	Agriculture	95,492	114,590	114,590	114,590	114,590	114,590	114,590
2	Livestock	57,899	69,479	69,479	69,479	50,977 (-26.6)[a]	36,530 (-47.4)	27,006 (-61.1)
3	Forestry	6,462	7,754	7,754	7,754	7,754	7,754	7,754
4	Fisheries	40,991	42,428	42,424	42,415	36,564 (-13.8)	24,695 (-41.8)	20,080 (-52.7)
5	Coal & Coal Prods.	8,632	9,251	9,251	9,251	9,251	9,251	9,251
6	Crude Oil & Natural Gas	5,794	6,334	6,334	6,334	6,334	6,334	6,334
7	Other Minerals	14,870	16,366	16,324	16,227 (-0.8)	15,138 (-7.5)	11,661 (-28.7)	9,592 (-41.4)
8	Food Manufacturing	267,750	330,396	330,000 (-0.1)	329,058 (-0.1)	221,945 (-32.8)	163,457 (-50.5)	112,152 (-66.1)
9	Textile & Apparel Prods.	318,927	478,391	478,391	478,391	347,089 (-27.4)	194,452 (-59.4)	160,467 (-66.5)
10	Wood & Wood Prods.	70,047	86,618	86,644	86,707 (+0.1)	63,190 (-27.0)	43,647 (-49.6)	34,844 (-59.8)
11	Pulp Paper & Allied	61,624	68,022	67,823 (-0.3)	67,349 (-1.9)	61,561 (-9.5)	43,585 (-35.9)	33,647 (-50.5)
12	Rubber & Rubber Prods.	22,332	24,126	24,040 (-0.4)	23,835 (-1.2)	21,269 (-11.8)	14,136 (-41.4)	11,42[illegible] (-52.7)
13	Petrochemical Prods.	43,133	86,266	86,266	86,266	42,460 (-50.8)	27,765 (-67.8)	21,664 (-74.9)
14	Other Chemicals	17,425	21,421	21,262 (-0.7)	20,883 (-2.5)	17,061 (-20.4)	12,295 (-42.6)	9,977 (-53.4)
15	Chemical Fertilizer	6,199	7,193	7,187 (-0.1)	7,173 (-0.3)	7,077 (-1.6)	6,750 (-6.2)	6,582 (-8.5)
16	Plastics & Plastic Prods.	141,554	156,839	155,242 (-1.0)	151,441 (-3.4)	127,090 (-19.0)	90,612 (-42.2)	65,549 (-58.2)
17	Misc. Chemical Prods.	40,623	45,045	44,960 (-0.2)	44,758 (-0.6)	38,484 (-14.6)	27,908 (-38.0)	21,443 (-52.4)
18	Petroleum Refining	104,082	125,132	135,906 (+8.6)	161,558 (+29.1)	110,234 (-11.9)	84,094 (-32.8)	74,157 (-40.7)
19	Cement & Cement Prods.	28,440	29,438	29,504 (+0.2)	29,661 (+0.8)	24,925 (-15.3)	18,210 (-38.1)	12,943 (-56.0)

Table 8.2 (Continued)

Code	Sector	Base Year (1979)	Basic Solution	Percentage Reduction in Aluminum Supply				
				35%	40%	50%	60%	70%
20	Misc. Nonmetal Prods.	27,653	30,223	29,918 (-1.0)	29,189 (-3.4)	35,761 (+18.3)	35,761 (+18.3)	35,761 (+18.3)
21	Steel & Iron	104,847	127,065	125,264 (-1.4)	120,974 (-4.8)	103,644 (-18.4)	72,921 (-42.6)	53,365 (-58.0)
22	Aluminum	6,860	6,860	6,860	6,860	6,860	6,860	5,566
23	Misc. Metals	6,575	8,809	8,419 (-4.4)	7,488 (-15.0)	5,539 (-37.1)	4,006 (-54.5)	2,837 (-67.8)
24	Metallic Prods.	63,937	70,993	69,244 (-2.5)	65,080 (-8.3)	49,105 (-30.8)	35,931 (-49.4)	25,284 (-64.4)
25	Machinery	54,994	98,826	98,759 (-0.1)	98,598 (-0.2)	82,382 (-16.6)	59,988 (-39.3)	41,849 (-57.7)
26	Electrical Equip.	196,408	392,816	356,624 (-9.2)	270,453 (-31.2)	161,065 (-59.0)	119,718 (-69.5)	81,082 (-79.4)
27	Transport Equip.	110,799	110,799	110,799	110,799	94,505 (-14.7)	61,114 (-44.8)	42,478 (-61.7)
28	Misc. Manufactures	56,528	57,757	57,728 (-0.1)	57,660 (-0.2)	47,611 (-17.6)	35,062 (-39.3)	24,143 (-58.2)
29	Construction	183,759	188,644	188,885 (+0.1)	189,458 (+0.4)	154,580 (-18.1)	113,923 (-39.6)	78,160 (-58.6)
30	Electricity	55,624	68,046	67,799 (-0.4)	67,213 (-1.2)	78,932 (+16.0)	78,932 (+16.0)	78,932 (+16.0)
31	Gas & City Water	11,144	12,276	12,281	12,292 (+0.1)	14,969 (+21.9)	7,660 (-37.6)	6,542 (-46.7)
32	Trans. & Commun.	118,662	128,573	128,352 (-0.2)	127,825 (-0.6)	115,419 (-10.2)	81,248 (-36.8)	68,367 (-46.8)
33	Wholesale & Retail Trade	189,942	202,084	201,341 (-0.4)	199,573 (-1.2)	237,379 (+17.5)	237,379 (+17.5)	237,379 (+17.5)
34	Misc. Services	409,967	571,289	585,836 (+2.5)	620,471 (+8.6)	612,668 (+7.2)	362,247 (-36.6)	306,869 (-46.3)

[a] The number in parentheses is the percentage change in sector's domestic output from the basic solution.
[b] Basic solution is derived from the basic model without a supply restriction.

solution are given in Column (2) of this table, together with the 1979 actual levels in Column (1). The output levels subject to a supply restriction are shown in the rest of the columns.

The order and extent of the changes in sectoral output levels in this table can be explained by their corresponding value-added coefficients and scarce resource input coefficients, which are also the major variables in the optimal allocation function. However, the sector's value-added coefficient is the most important factor in these changes. This is because our objective function in this model is to maximize the total value-added (GDP). For example, the largest output changes during a 40 percent cut in aluminum supply are in sectors 26 and 23 (electrical equipment and miscellaneous metals, respectively), which also have the lowest value-added coefficients among the major aluminum using sectors. Table 8.3 lists the sector's value-added and aluminum input coefficients. The other scarce resource input coefficients are presented in Appendix C.

The impact of aluminum supply restrictions with the substitution effect are listed in the last three columns of Table 8.1. The optimal levels of each sector's output with the substitution effect are presented in Table 8.4. From these results, the effects of substitution are found to be quite profound. The GDP loss from a 50 percent reduction in aluminum supply with substitution will decrease to 0.3 percent, while the GDP loss during a 70 percent reduction will decrease to only 20.5 percent. When the substitution effect is incorporated into the model, the level of each sector's output, excluding the major aluminum

Table 8.3

VALUE-ADDED AND DIRECT INPUT COEFFICIENTS FOR ALUMINUM

Code	Sector	Value-Added Coefficient	Aluminum Direct Input Coefficient
1	Agriculture	0.677	0
2	Livestock	0.077	0
3	Forestry	0.889	0
4	Fisheries	0.606	0
5	Coal & Coal Prods.	0.479	0
6	Crude Oil & Natural Gas	0.854	0
7	Other Minerals	0.596	0
8	Food Manufacturing	0.254	0.0001
9	Textile & Apparel Prods.	0.284	*
10	Wood & Wood Prods.	0.332	0.0001
11	Pulp Paper & Allied	0.350	0.0009
12	Rubber & Rubber Prods.	0.385	0
13	Petrochemical Prods.	0.242	0
14	Other Chemicals	0.310	0.0001
15	Chemical Fertilizer	0.208	0
16	Plastics & Plastic Prods.	0.286	0.0008
17	Misc. Chemical Prods.	0.286	0.0015
18	Petroleum Refining	0.162	0
19	Cement & Cement Prods.	0.485	0
20	Misc. Nonmetal Prods.	0.443	*
21	Steel & Iron	0.226	*
22	Aluminum	0.160	0.4939
23	Misc. Metals	0.248	0.0016
24	Metallic Prods.	0.357	0.0410
25	Machinery	0.361	0.0054
26	Electrical Equip.	0.293	0.0088
27	Transport Equip.	0.332	0.0111
28	Misc. Manufactures	0.410	0.0029
29	Construction	0.366	0.0012
30	Electricity	0.446	0
31	Gas & City Water	0.322	0
32	Transp. & Communication	0.580	0
33	Wholesale & Retail Trade	0.740	0
34	Misc. Services	0.723	0.0002

Notes: "0" indicates no aluminum input in the sector.
"*" indicates aluminum input coefficient less than 0.0001.

TABLE 8.4

THE EFFECT OF SUBSTITUTION ON DOMESTIC GROSS OUTPUT
(NT millions)

Code	Sector	40%[a]		50%		60%		70%	
		No substitution	With substitution	No substitution	With substitution	No substitution	With substitution	No substitution	With substitution
1	Agriculture	114590	114590	114590	114590	114590	114590	114590	114590
2	Livestock	69479	69479	50977	67206	36530	69479	27006	34890
3	Forestry	7754	7754	7754	7754	7754	7754	7754	7754
4	Fisheries	42415	42420	36564	41351	24695	49189	20080	20873
5	Coal & Coal Prods	9251	9251	9251	9251	9251	9251	9251	9251
6	Crude Oil & Natural Gas	6334	6334	6334	6334	6334	6334	6334	6334
7	Other Minerals	16227	16275	15138	17094	11661	19189	9592	12050
8	Manufacturing Food	329058	329526	221945	321300	163457	321300	112152	145209
9	Textile & Apparel Prods	478391	478391	347089	478391	194452	478391	160467	386956
10	Wood & Wood Prods	86707	86676	63190	84056	43647	84056	34844	38499
11	Pulp Paper & Allies	67349	67585	61561	77467	43585	60005	33647	50037
12	Rubber & Rubber Prods	23835	23937	21269	28398	14136	28398	11420	13946
13	Petrochemical Prods	86266	86266	42460	86266	27765	86266	21664	38621
14	Other Chemicals	20883	21072	17061	25008	12295	25008	9977	13710
15	Chemical Fertilizer	7173	7179	7077	7320	6750	7131	6582	6715
16	Plastics & Plastic Prods	151441	153331	127090	182800	90612	114857	65549	95606
17	Misc Chemical Prods	44758	44858	38484	43845	27908	37506	21443	30277
18	Petroleum Refining	161558	148805	110234	143568	84094	118112	74157	87093
19	Cement & Cement Prods	29661	29583	24925	34858	18210	34858	12943	17189
20	Misc Nonmetal Prods	29189	29551	35761	35761	35761	35761	35761	35761
21	Steel & Iron	120974	123107	103644	133798	72921	147526	53365	68455
22	Aluminum	6860	6860	6860	6860	6860	6860	5566	5566
23	Misc Metals	7488	7951	5539	10609	4006	4882	2837	3653
24	Metallic Prods	65080	67150	49105	54965	35931	44810	25284	33124
25	Machinery	98598	98678	82382	109284	59988	68260	41849	56096
26	Electrical Equip	270453	313292	161065	162689	119718	124040	81082	103677
27	Transport Equip	110799	110799	94505	96655	61114	67114	42478	53388
28	Misc Manufactures	57660	57694	47611	48402	35062	37956	24143	31762
29	Construction	189458	189173	154580	155379	113923	121068	78160	102810
30	Electricity	67213	67504	78932	67-73	78932	71061	78932	78932
31	Gas & City Water	12292	12286	14969	14969	7660	14969	6542	14969
32	Trans. & Communication	127825	128087	115419	144743	81248	149714	68367	79060
33	Wholesale & Retail Trade	199573	200452	237397	237379	237379	237379	237379	237379
34	Misc Services	620471	603253	612668	612668	362247	612668	306869	612668

[a]The percentage indicates the size of supply reduction as percentage of total.

using sector, is not affected by much until the supply reduction rises above 50 percent. This fact once more indicates that I-O impact analysis will over-estimate the analytical results because it fails to incorporate substitution.

Table 8.5 represents the rankings of each sector's percentage changes in domestic output due to aluminum supply reductions. The ranking of sectoral output in the basic solution is relative to the actual levels in 1979. A sector with a higher rank indicates the increase in its output is relatively larger than other sectors. These rankings will tell us, subject to the constraints formulated in Chapter VII, which sectors deserve more incentive to increase their output in order to maximize GDP. The rankings of the optimal levels of each sector's output for a restriction in aluminum supply corresponds to the output level in the basic solution rather than the actual level in 1979. Therefore, a sector with a higher rank means that it will be affected by the supply reduction less than the sector with a lower rank. In other words, a cut in aluminum supply will affect the output level more significantly in the sector with a lower rank. From the comparison of these rankings together with the changes in sector's output shown in Tables 8.2 and 8.4, we have a clear idea about the relative effects of a cut in aluminum supply. This comparison also illustrates the point made earlier about the importance of the sector's value-added coefficient and the reason why the GDP loss increases substantially during a cut in aluminum supplies above 50 percent.

Table 8.5

RANKING OF SECTORAL DOMESTIC OUTPUT BY ITS PERCENTAGE CHANGE DUE TO A SUPPLY RESTRICTION

Code	Sector	Basic Solution	35%	Percentage of Reduction in Aluminum Supply							
				40%		50%		60%		70%	
				A	B	A	B	A	B	A	B
1	Agriculture	--	--	--	--	--	--	--	--	--	--
2	Livestock	1	7	7	7	22	24	22	13	21	22
3	Forestry	--	--	--	--	--	--	--	--	--	--
4	Fisheries	25	11	7	7	12	20	17	10	12	23
5	Coal & Coal Prods.	--	--	--	--	--	--	--	--	--	--
6	Crude Oil & Natural Gas	--	--	--	--	--	--	--	--	--	--
7	Other Minerals	20	12	18	18	7	15	5	6	6	8
8	Food Manufacturing	9	13	12	15	26	22	25	17	24	26
9	Textile & Apparel Prods.	5	7	7	7	24	17	27	13	26	7
10	Wood & Wood Prods.	8	19	19	18	8	10	24	18	21	18
11	Pulp Paper & Allied	18	19	19	18	8	10	7	20	10	8
12	Rubber & Rubber Prods.	23	20	20	20	10	5	16	4	12	16
13	Petrochemical Prods.	1	7	7	7	28	17	28	13	28	27
14	Other Chemicals	10	23	23	23	21	7	19	7	14	12
15	Chemical Fertilizer	14	13	15	14	6	16	4	16	4	6
16	Plastics & Plastic Prods.	17	24	24	24	20	8	18	22	18	14
17	Misc. Chemical Prods.	16	17	16	16	13	21	11	21	11	11
18	Petroleum Refining	13	1	1	1	11	9	6	19	5	10
19	Cement & Cement Prods.	25	3	3	3	15	3	12	2	15	15
20	Misc. Nonmetal Prods.	21	24	24	24	2	4	1	3	1	2
21	Steel & Iron	12	26	26	26	19	14	19	9	17	21
22	Aluminum	--	--	--	--	--	--	--	--	--	--

Table 8.5 (Continued)

Code	Sector	Basic Solution	35%	40% A	40% B	50% A	50% B	60% A	60% B	70% A	70% B
				Percentage of Reduction in Aluminum Supply							
23	Misc. Metals	7	28	28	28	27	2	26	28	27	28
24	Metallic Prods.	15	27	27	27	25	28	23	26	24	25
25	Machinery	4	13	13	12	16	12	13	23	16	17
26	Electrical Equip.	1	29	29	29	29	29	29	29	29	29
27	Transport Equip.	29	7	7	7	14	25	21	27	23	24
28	Misc. Manufactures	28	13	13	12	17	26	13	25	18	19
29	Construction	27	4	4	4	18	27	15	25	20	20
30	Electricity	11	20	20	20	4	19	3	12	3	4
31	Gas & City Water	19	6	5	5	1	1	10	1	3	1
32	Transp. & Commun.	22	17	16	16	9	11	9	8	9	13
33	Wholesale & Retail Trade	24	20	20	20	3	6	2	5	2	3
34	Misc. Services	6	2	2	2	5	13	8	11	7	5

Notes: A - no substitution effect
B - with substitution effect

The changes in employment due to the supply reductions are listed in Table 8.6. The shortage of skilled labor will continue until a cut above 50 percent. Below a 50 percent reduction, only the unskilled labor will be affected. Besides, a larger cut in aluminum supply will shrink the demand for skilled labor more quickly than the demand for unskilled labor. This is because most of aluminum is required by the manufacturing industries, the major demand market for skilled labor.

Changes in final demand due to an aluminum supply restriction are presented in Table 8.7. These results show the impact of a supply restriction on each sector's final demand and give the levels of a sector's export activity and household consumption. For example, the optimal final demand level of sector 1 (agriculture) is close to the minimum final demand during a supply reduction of less than 50 percent. This means the level of the final demand (export activity and household consumption) will not be affected very much by levels of a reduction below 50 percent. But, for a reduction above 50 percent, the optimal demand level will increase substantially. This is because, based on the optimal adjustment pattern, sector 1 is encouraged to maintain its output level in order to maximize GDP. Thus all of the excess supply due to rapidly decreasing intermediate demand for the output of sector 1 go to the final demand. This large increase in final demand implies that the export activity or household consumption of sector 1 should be enforced in order to shrink the GDP loss. Otherwise, the inventory of sector 1 will be forced to increase dramatically. If

Table 8.6

CHANGES IN EMPLOYMENT DUE TO ALUMINUM SUPPLY RESTRICTIONS
(thousand man-years)

	Total Labor	Basic Solution	35%	Percentage Reduction in Aluminum Supply							
				40%		50%		60%		70%	
				A	B	A	B	A	B	A	B
Skilled Labor (SL)	1,841	1,841	1,841	1,841	1,841	1,668	1,841	1,208	1,698	1,000	1,394
Non-Skilled Labor (NSL)	6,404	6,372	6,354	6,309	6,331	5,769	6,321	4,827	6,098	4,362	5,248
Unemployment Rate of SL (%)		--	--	--	--	9.4	--	34.4	7.7	45.7	24.3
Unemployment Rate of NSL (%)		0.5	0.8	1.5	1.1	9.9	1.3	24.6	4.8	31.9	18.0
Total Unemployment Rate (%)		0.4	0.6	1.1	0.9	9.4	1.0	26.5	5.1	34.7	19.1

Notes: A - no substitution effect
B - with substitution effect

Table 8.7

CHANGES IN FINAL DEMAND DUE TO ALUMINUM SUPPLY RESTRICTIONS
(NT millions)

Code	Sector	Minimum Final Demand	Basic Solution	35%[a]	40% A	40% B	50% A	50% B	60% A	60% B	70% A	70% B
1	Agriculture	33200	34025	34104	34291	34198	75756	35714	102725	36998	121767	100456
2	Livestock	10358	10359	10359	10359	10359	9400	9400	6267	11545	5223	5223
3	Forestry	2577	2578	2578	2578	2578	11837	3102	20321	3447	24112	21847
4	Fisheries	34848	34936	34936	34936	34936	31363	34046	20909	41807	17242	17242
5	Coal & Coal Prods	382	382	382	382	382	344	344	229	267	191	191
6	Crude Oil & Natural Gas	3240	3240	3240	3240	3240	2916	2916	1944	2268	1620	1620
7	Other Minerals	890	890	890	890	890	1272	1272	848	6158	707	707
8	Manufacturing Food	198904	261506	260698	259698	260331	169209	253600	126931	252198	84621	105776
9	Textile & Apparel Prods	171488	280211	280315	259073	280440	199980	279204	109024	284368	90853	230246
10	Wood & Wood Prods	39705	54303	54642	55448	55047	38365	56127	25577	59812	21314	21314
11	Pulp Paper & Allies	10494	14094	14094	14094	14094	14544	22137	10908	10908	7272	9090
12	Rubber & Rubber Prods	13357	13357	13357	13357	13357	12541	18192	8360	19747	6967	6967
13	Petrochemical Prods	4998	42719	42831	43098	42965	4498	38206	2999	49352	2499	2499
14	Other Chemicals	2101	2102	2102	2102	2102	3181	7281	2020	10043	1767	1767
15	Chemical Fertilizer	282	291	291	291	291	406	406	271	316	226	226
16	Plastics & Plastic Prods	56890	56850	56850	56850	56850	50766	86652	38074	38074	25383	31728
17	Misc Chemical Prods	18002	18002	18002	18002	18002	16834	16834	12626	12626	8418	10522
18	Petroleum Refining	30588	35271	47189	75565	61458	28297	50895	18865	22009	15725	15725
19	Cement & Cement Prods	989	990	990	990	990	1043	10113	695	14542	580	580
20	Misc Nonmetal Prods	10282	10284	10284	10284	10284	21743	20524	26921	23351	30553	26895
21	Steel & Iron	17795	17795	17795	17795	17795	20899	39105	13933	76541	11615	11615
22	Aluminum	87	87	87	87	87	87	87	87	87	87	87
23	Misc Metals	1518	1531	1531	1531	1531	1468	11626	979	1142	653	653
24	Metallic Prods	27326	27528	27528	27528	27528	22013	22013	16510	16510	11006	13758
25	Machinery	76687	76687	76687	76687	76688	63786	68729	47840	47840	31894	39867
26	Electrical Equip	161171	337489	304471	225858	264940	128937	128937	96703	96703	64469	80586
27	Transport Equip	85085	99794	99779	99743	99761	84092	84092	53461	53461	35641	44551
28	Misc Manufactures	64341	64341	64341	64341	64341	52530	52530	39397	39397	26265	32831
29	Construction	169738	169738	169738	169738	169738	135790	135790	101843	101843	67895	84867
30	Electricity	11865	11865	11865	11865	11865	30922	10680	43748	17214	49291	36445
31	Gas & City Water	6642	6642	6642	6642	6642	9671	9201	4010	9346	3342	10117
32	Transp. & Communication	83945	83946	83946	83946	83946	76020	102558	50680	111720	42234	42243
33	Wholesale & Retail Trade	124127	124127	124127	124127	124127	176759	164489	194329	171803	204631	191392
34	Misc Services	300736	437256	454662	496104	475501	509114	485990	271656	495456	227732	529967

Notes: A--no substitution effect; B--with substitution effect.

[a]The percentage indicates the size of supply reduction as percentage of total.

the sectoral optimal final demand is less rather than more than the minimum final demand, satisfying the minimum final demand is impossible. The export activity or consumption of the sector should be forced down. The shadow prices of the minimum final demand constraints, shown in Table 8.8, present the changing pattern in each sector's optimal final demand. These shadow prices tell us the marginal costs of an extra unit increase in final demand constraints, which also indicate by how much the objective function (GDP) is affected, per unit change in the minimum final demand constraints. For example, the shadow price of sector 2 is 0.174 in the basic solution. It tells us that a change of one unit of the minimum final demand constraint will cost 0.174 unit of GDP. The zero-level shadow prices for sector 1, 8, 9, 10, 13, 26, 27, and 34 in the basic solution indicate any change in the minimum final demand constraints for these sectors will not cause any cost to the economy. In other words, export activity and consumption in these sectors should be encouraged. For sectors 5 and 6, the output levels are predetermined. Any changes in their final demand will directly affect the imports of these sectors only. It will not cause any change in any other sector's output. Therefore, although the shadow prices for the two sectors are zero, it does not imply that increasing their final demand is worthwhile. However, the change patterns of the shadow prices together with the optimal final demand shown in Table 8.7 are of great importance to the policy makers. They help to set up a strategy to reduce the cost of a reduction in aluminum supply.

Table 8.9 shows shadow prices for the upper bounds on a sector's output. These shadow prices tell us the gain or loss from the changes of

Table 8.8

SHADOW PRICES FOR SECTORAL FINAL DEMAND CONSTRAINTS

Code	Sector	Basic Solution	Percentage Changes in Aluminum Supply				
			35%	40%	50%	60%	70%
1	Agriculture	--	--	--	--	--	--
2	Livestock	0.174	0.162	0.162 (0.161)	0.334 (0.068)	0.578 (-)	0.578 (0.211)
3	Forestry	0.109	0.107	0.107 (0.107)	--	--	--
4	Fisheries	0.875	0.874	0.874 (0.874)	0.138 (-)	0.438 (-)	0.438 (0.083)
5	Coal & Coal Prods	--	--	--	--	--	--
6	Crude Oil & Natural Gas	--	--	--	--	--	--
7	Other Minerals	0.882	0.881	0.881 (0.881)	0.265 (0.033)	0.529 (-)	0.529 (0.207)
8	Manufacturing Food	--	--	--	0.531 (-)	0.854 (-)	0.854 (-)
9	Textile & Apparel Prods	--	--	--	--	0.201 (-)	0.201 (-)
10	Wood & Wood Prods	--	--	--	0.128 (-)	0.327 (-)	0.327 (0.128)
11	Pulp Paper & Allies	0.126	0.128	0.128 (0.128)	0.882 (-)	1.394 (0.063)	1.394 (1.107)
12	Rubber & Rubber Prods	0.219	0.219	0.219 (0.219)	0.117 (-)	0.337 (-)	0.337 (0.097)
13	Petrochemical Prods	--	--	--	0.186 (-)	0.352 (-)	0.352 (0.151)
14	Other Chemicals	0.121	0.121	0.121 (0.121)	0.255 (-)	0.454 (-)	0.454 (0.234)
15	Chemical Fertilizer	0.318	0.319	0.319 (0.319)	0.630 (0.037)	1.010 (0.022)	1.010 (0.563)
16	Plastics & Plastic Prods	0.053	0.057	0.057 (0.057)	1.077 (-)	1.659 (0.150)	1.650 (1.249)
17	Misc Chemical Prods	0.162	0.166	0.166 (0.166)	1.231 (0.013)	1.787 (0.318)	1.737 (1.427)
18	Petroleum Refining	--	--	--	0.124 (-)	0.228 (0.004)	0.228 (0.103)
19	Cement & Cement Prods	0.231	0.229	0.229 (0.229)	0.276 (-)	0.610 (-)	0.610 (0.215)
20	Misc Nonmetal Prods	0.245	0.243	0.243 (0.243)	--	--	--
21	Steel & Iron	0.296	0.297	0.297 (0.297)	0.445 (-)	0.703 (-)	0.703 (0.393)
22	Aluminum	--	2.705	2.705 (2.863)	805.642 (27.94)	1097.185 (327.7)	1097.185 (1010.3)
23	Misc Metals	0.104	0.107	0.107 (0.108)	1.193 (-)	1.683 (0.358)	1.683 (1.270)
24	Metallic Prods	0.152	0.256	0.256 (0.256)	35.074 (0.813)	42.479 (10.46)	42.476 (28.31)
25	Machinery	0.293	0.309	0.309 (0.309)	5.243 (-)	7.409 (1.503)	7.309 (4.754)
26	Electrical Equip	--	--	--	9.436 (0.080)	13.003 (2.983)	13.003 (8.600)
27	Transport Equip	--	--	--	9.552 (0.262)	13.161 (3.043)	13.161 (8.715)
28	Misc Manufactures	0.418	0.424	0.424 (0.425)	2.065 (0.203)	2.970 (0.585)	2.970 (2.496)
29	Construction	0.691	0.692	0.692 (0.692)	1.147 (0.044)	1.771 (0.109)	1.771 (1.043)
30	Electricity	1.947	1.932	1.932 (0.932)	--	--	--
31	Gas & City Water	0.017	0.016	0.016 (0.016)	--	0.025 (-)	0.025 (-)
32	Transp. & Communication	0.051	0.050	0.050 (0.050)	0.058 (-)	0.291 (-)	0.291 (0.007)
33	Wholesale & Retail Trade	0.084	0.083	0.083 (0.083)	--	--	--
34	Misc Services	-	--	--	--	--	--

Note: The number in parentheses indicates the shadow price with substitution effect.

Table 8.9

SHADOW PRICES FOR SECTORAL OUTPUT CONSTRAINTS

Code	Sector	Basic Solution	35%[a]	40%		50%		60%		70%	
				A	B	A	B	A	B	A	B
1	Agriculture	-0.612	-0.612	-0.612	-0.612	-0.462	--	-0.366	-0.609	-0.366	-0.469
2	Livestock	-0.072	-0.061	-0.061	--	--	--	--	-0.062	--	--
3	Forestry	-1.109	-1.101	-1.101	-1.101	-0.718	-0.754	-0.643	-0.826	-0.643	-0.734
4	Fisheries	--	--	--	--	--	--	--	--	--	--
5	Coal & Coal Prods	2.324	2.321	2.321	2.321	0.258	0.502	0.538	-0.226	0.538	0.195
6	Crude Oil & Natural Gas	-0.191	-0.190	-0.190	-0.190	0.215	-0.540	0.614	-0.460	0.614	0.125
7	Other Minerals	--	--	--	--	--	--	--	-0.253	--	--
8	Manufacturing Food	--	--	--	--	--	-0.099	--	-0.005	--	--
9	Textile & Apparel Prods	-0.084	-0.084	-0.084	-0.084	--	-0.095	--	-0.203	--	--
10	Wood & Wood Prods	--	--	--	--	--	-0.131	--	-0.179	--	--
11	Pulp Paper & Allies	--	--	--	--	--	-0.067	--	--	--	--
12	Rubber & Rubber Prods	--	--	--	--	--	-0.092	--	-0.227	--	--
13	Petrochemical Prods	-0.017	-0.016	-0.016	-0.016	--	-0.126	--	-0.091	--	--
14	Other Chemicals	--	--	--	--	--	-0.078	--	-0.089	--	--
15	Chemical Fertilizer	--	--	--	--	--	--	--	--	--	--
16	Plastics & Plastic Prods	--	--	--	--	--	-0.072	--	--	--	--
17	Misc Chemical Prods	--	--	--	--	--	--	--	--	--	--
18	Petroleum Refining	--	--	--	--	--	--	--	--	--	--
19	Cement & Cement Prods	--	--	--	--	--	-0.064	--	-0.202	--	--
20	Misc Nonmetal Prods	--	--	--	--	-0.185	-0.004	-0.040	-0.347	-0.040	-0.200
21	Steel & Iron	--	--	--	--	--	--	--	--	--	--
22	Aluminum	0.669	-0.703	-0.703	-0.783	-407.7	-13.92	-555.1	-165.9	-555.1	-511.3
23	Misc Metals	--	--	--	--	--	-0.018	--	--	--	--
24	Metallic Prods	--	--	--	--	--	--	--	--	--	--
25	Machinery	--	--	--	--	--	--	--	--	--	--
26	Electrical Equip	-0.029	--	--	--	--	--	--	--	--	--
27	Transport Equip	--	--	--	--	--	--	--	--	--	--
28	Misc Manufactures	--	--	--	--	--	--	--	--	--	--
29	Construction	--	--	--	--	--	--	--	--	--	--
30	Electricity	--	--	--	--	-0.342	--	-0.280	--	-0.280	-0.354
31	Gas & City Water	--	--	--	--	-0.093	-0.082	--	-0.193	--	-0.115
32	Trans. & Communication	--	--	--	--	--	--	--	--	--	--
33	Wholesale & Retail Trade	--	--	--	--	-0.625	-0.241	-0.564	-0.696	-0.564	-0.629
34	Misc Services	--	--	--	--	-0.213	-0.490	--	-0.562	--	-0.187

Notes: A--no substitution effect; B--with substitution.

[a]The percentage indicates the size of supply reduction as percentage of total.

one unit of these output constraints. For example, the numerically largest shadow price during a 70 percent reduction in aluminum supply without incorporating substitution is for the aluminum sector, which has a value -555.1. This means that a change of one unit of the aluminum supply will increase 555.1 unit in GDP. The zero-level shadow prices indicate that any of these constraints can increase or decrease by one unit without affecting the GDP loss. Therefore, Table 8.9 can tell the policy makers which sector deserves more incentive to increase its output level in order to guard against a loss of GDP. However, these results should be linked together with the changes in final demand shown in Table 8.7. Having a sector with a higher shadow price for its output constraint does not mean that increasing its output will absolutely benefit the whole economy. If extra export or consumption in this sector, due to a dramatic increase in its final demand is impossible, the decision to increase this sector's output level will be problematic to the economy. Setting up an optimal adjustment strategy for the policy makers is beyond our study, because more data and governmental judgement on the national security and other considerations are needed. However, these simulation results give the general idea about the optimal adjustment pattern during each level of the reduction in aluminum supply.

C. THE OPTIMAL ALLOCATION FUNCTION

In Section B, the results of the simulation are presented and the implications of these results are illustrated. In this section, we present the optimal allocation function derived from these results.

In general, the optimal levels of output during a reduction in aluminum supply shown in Tables 8.2 and 8.4 are not to be used as a direct guide by the policy makers to set up the optimal adjustment strategy. The stimulation of the output levels which approach the optimal levels is not easy. However, the optimal allocation coefficients derived from the simulation results will reconcile this problem. As mentioned above, the domestic primary aluminum industry is dominated by Talco, which is owned by the government. If it is necessary, the government has enough power to control the allocation function. For this reason, the optimal allocation function will have much meaning for the government.

Table 8.10 represents the optimal allocation coefficients during each level of the reduction in aluminum supply. They are derived from the optimal output levels for aluminum using sectors multiplied by their corresponding aluminum input coefficients. Based on the allocation coefficients, the output levels in these sectors will endogenously approach the optimal levels as indicated in the simulation results.

Table 8.10

THE OPTIMAL ALLOCATION COEFFICIENTS DUE TO SUPPLY REDUCTIONS

Code	Sector	Base Year (1979)	Basic Solution	40%[a]		50%		60%		70%	
				A	B	A	B	A	B	A	B
8	Manufacturing Food	0.0016	0.0027	0.0030	0.0030	0.0024	0.0035	0.0022	0.0043	0.0020	0.0026
9	Textile & Apparel Prods	0.0005	0.0007	0.0009	0.0009	0.0007	0.0010	0.0005	0.0012	0.0006	0.0014
10	Wood & Wood Prods	0.0004	0.0007	0.0008	0.0008	0.0007	0.0009	0.0006	0.0011	0.0006	0.0007
11	Pulp Paper & Allies	0.0052	0.0049	0.0054	0.0055	0.0060	0.0075	0.0053	0.0073	0.0054	0.0081
14	Other Chemicals	0.0001	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0002	0.0002
16	Plastics & Plastic Prods	0.0111	0.0101	0.0109	0.0110	0.0110	0.0158	0.0098	0.0124	0.0094	0.0137
17	Misc Chemical Prods	0.0058	0.0054	0.0060	0.0060	0.0062	0.0071	0.0056	0.0076	0.0058	0.0082
21	Steel & Iron	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0006	0.0003	0.0004
22	Aluminum	0.3211	0.2721	0.3044	0.3044	0.3652	0.3652	0.4565	0.4565	0.4939	0.4939
23	Misc Metals	0.0010	0.0011	0.0011	0.0011	0.0010	0.0018	0.0009	0.0011	0.0008	0.0011
24	Metallic Prods	0.2485	0.2338	0.2397	0.2326	0.2170	0.2196	0.1985	0.2089	0.1862	0.1774
25	Machinery	0.0283	0.0429	0.0278	0.0450	0.0480	0.0575	0.0436	0.0419	0.0406	0.0395
26	Electrical Equip	0.1631	0.2777	0.2138	0.2328	0.1528	0.1395	0.1419	0.1242	0.1282	0.1191
27	Transport Equip	0.1038	0.0998	0.1105	0.1039	0.1131	0.1045	0.0914	0.0847	0.0847	0.0774
28	Misc Manufactures	0.0158	0.0135	0.0150	0.0150	0.0149	0.0151	0.0137	0.0148	0.0126	0.0165
29	Construction	0.0216	0.0182	0.0204	0.0192	0.0200	0.0182	0.0184	0.0165	0.0169	0.0161
34	Misc Services	0.0067	0.0092	0.0111	0.0108	0.0132	0.0132	0.0098	0.0165	0.0110	0.0220

Note: A--No substitution effect; B--With substitution effect

[a]The percentage indicates the size of supply reduction as percentage of total.

CHAPTER IX

CONCLUSION AND EXTENSIONS

A. EVALUATION OF THE MODEL

There is a growing concern over the impact of critical mineral supply restrictions on the economies of mineral importing nations such as Taiwan. The objective of this dissertation is to build a framework that can be used to analyze the impact of a mineral supply restriction and can be used to formulate an optimal adjustment pattern for a national economy. The major contributions of this study are two-fold: (1) to advance state-of-the-art input-output modeling by incorporating substitution of input materials into its solution, and (2) to derive the optimal allocation function for policy-makers to construct a feasible strategy to minimize the loss from a supply disruption.

The models developed and tested in Chapter III, IV, VI, VII and VIII each have their strengths and weaknesses. However, as a group they have proven reasonably good in their ability to show the impact of a supply restriction and to present an optimal response. The domestic demand model developed in Chapter III has been used in Chapter IV to predict the changes in the price level in order to force a specific reduction in domestic aluminum demand during a supply restriction. The model is simply a static model, but it is reasonably accurate in its ability to depict the relationship between the demand level and the price level.

The elasticity of substitution between aluminum and copper estimated in Chapter IV is very low, which indicates little potential for the widespread replacement of aluminum with copper. The low elasticity may be attributed primarily to two factors. First, most of the increase in aluminum demand in Taiwan in the past decade might have been induced by output effects stemming from high growth rate in real GDP and substantial expansion in export activities. Therefore, the price effect in aluminum demand is relatively small. Second, any changes in the aluminum price will shift the cost advantage of aluminum as an input. This shifting might simply cause shrinking in export activities of some final products. The forced substitution between aluminum and copper may not be absolutely necessary. However, even if the elasticity of substitution between aluminum and copper is very low, an impact analysis that omits the substitution effect would still significantly overestimate the impact of a supply restriction, as indicated in Chapter VI and VIII, respectively.

Contrasting the results in Chapter VI, where the conventional analytical frameworks (consumers' surplus analysis and I-O analysis) for impact analysis were presented, with the results in Chapter VII (the LP model), some implications were noted. First, both consumers' surplus analysis and the "supply-driven" I-O model overestimate the impact in the case of a mild supply restriction, and underestimate the impact in the case of a severe supply restriction. For example, as a result of a 10 percent reduction in aluminum supply, the real GDP is reduced by around 0.1 percent in consumers' surplus analysis and I-O analysis, but there is no reduction in real GDP based on the model presented in Chapter VII. The 70 percent cut in aluminum supply shrinks real GDP by 2.0 percent in consumers' surplus analysis and

0.6 percent in I-O analysis, but by 44.0 percent in the LP model. The reason for the biased estimation in the case of a mild supply restriction is that both consumers' surplus analysis and I-O analysis are unable to handle the production function and the allocation function simultaneously. In the open economy, it is easy to adjust the output structure due to a small change in the allocation function during a mild supply restriction. Thus most of the impact will simply cause a transfer of inputs among some sectors in the economy. However, in the case of a severe supply restriction, the whole economy's output structure will be greatly affected through direct and indirect effects. A simple transfer adjustment will not be enough to alleviate the impact, and a major reallocation will violate practical constraints. Conceptually, the increase in the economic loss will not be a simple linear multiplicative increase, as in the case of a mild supply restriction. However, because of the rigid assumption of a fixed unit change in gross output due to each unit change in commodity supply, the I-O analysis cannot include this result. Also, consumers' surplus analysis focuses primarily on the impact on the aluminum sector itself (partial equilibrium analysis). Therefore, the impact of indirect effects are not captured.

The LP model presented in Chapter VII is better able to provide the accurate results in analyzing the impact of a supply restriction since it is a general equilibrium solution. Its results also reflect the conceptual discontinuity of supply restriction impacts. Moreover, within the framework, the optimal allocation function for aluminum is easily derived. This allocation function is a very important innovation in this study, since it allows policy-makers to easily construct an optimal adjustment strategy.

B. INTERACTIVE LP SOLUTIONS

In the model presented in Chapter VII, the piece-wise procedure plays a very important role. It will prevent policy responses from including infeasible changes in sectoral outputs. This is a very important point in modeling an optimal adjustment policy, because many drastic solutions will be infeasible to policy-makers. It is obvious that given different assumptions as to the percentage change in minimum final demand constraints for each step or different piecewise procedures, (e.g. different and nonuniform final demand changes) the solution will be different. Therefore, the procedures developed are flexible enough to be applied to most specific policy tasks.

C. POSSIBLE EXTENSIONS OF THE MODEL

There are a number of extensions of the present study. With regard to evaluating the substitution between aluminum and copper, two further studies might be attempted. The first would be to estimate the elasticity of substitution on a disaggregated (I-O sector) basis. Substitution potential is generally expected to be different across sectors but it is not known a priori how much this will affect the results. Another suggestion is to broaden the substitution analysis by including all other substitutes such as: plastic and steel in the model. This might significantly affect the extent and flexibility of adjustment during a supply restriction.

For the LP model, the most important recommendation for the further study is to further disaggregate the sectors, especially for the aluminum using sectors. This is because the assumption of fixed input coefficients in a more aggregate I-O table may overestimate the impact of a supply restriction. For example, the aluminum input coefficient for sector 17 (miscellaneous chemical products) is 0.0015. The domestic output in this sector was NT$40,623 in 1979. Based on the assumption of fixed input coefficients and assuming no technological change in the current period, this input coefficient implies that 15 dollars decrease in aluminum supply would cause a 10,000 dollar output decline in sector 17. However, sector 17 includes two subsectors: medicines and other miscellaneous chemical products. If these two subsectors could be disaggregated on the average (i.e., same amount output for each subsector) and we simply assumed no aluminum input was required for the medicines sector, then the aluminum input coefficient for other miscellaneous chemical products sector would become 0.003 instead of 0.0015. Therefore, the same 15 dollar decrease in aluminum supply for these two subsectors would directly cause only 5,000 dollar output decline in these two subsectors (i.e., sector 17). Although the more disaggregate LP model will cost much more money and require much more data than the aggregate one, it is worthwhile.

While this model has been used to analyze the impact of a reduction in aluminum supply, its framework could also be applied to other commodities or domestic scarce resources such as: electricity and energy. Because the optimal allocation function can be easily derived from the model, it could also be used to provide strategies for different policy tasks by changing the objective function or some constraints. Finally, another possible extension of the model is to apply a recursive LP technique together with the analytical framework presented here, to analyze the long-run impact of a supply restriction based on the dynamic I-O model. This would be of great importance for providing the optimal strategy for a long-run supply restriction.

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APPENDIX A

THE TAIWAN ECONOMIC SETTING*

Taiwan, one of the more rapidly developing countries, has an area of 35,981 sq. km., and a population of 18.136 million. In 1981, Taiwan's GNP was NT$1,703.713 billions at current prices, the equivalent of US $44.965 billion; the per capita GNP was NT$96,867, the equivalent of US $2,570. The inflation rate in 1981 was 7.6 percent. Except the years of 1973 and 1974, the real average growth rate of GNP in past two decades was around 10 percent, the real average growth rate of per capita GNP was about 8 percent, and the inflation rate varied from 1.4 percent to 13.8 percent. In 1973 and 1974, due to the energy crisis, the growth rates of GNP were only 1.1 percent and 4.2 percent; the growth rates of per capita GNP declined to -0.7 percent and 2.3 percent; and the inflation rates jumped substantially to 22.9 percent and 40.6 percent. From the above figures we can easily conclude that the energy supply shortage had a very serious impact on Taiwan's economic development. This is because Taiwan imports about 85 percent of domestic energy demand, including all the oil demand. Likewise, Taiwan has very limited mineral resources especially the metal minerals. Almost all the metal minerals rely on imports. Hence, the prediction of the impact of a supply shortage in metals will be very important to Taiwan economy.

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*The information summarized here comes principally from CEPD's The ROC's Four-Year Plan (1982-1985), 1983 and Industry of Free China, 1983.

The major forces promoting rapid economic growth in Taiwan are appropriate development planning and rapid export expansion. Foreign trade by Taiwan in 1981 was US $43.8 billion. This amount included US $22.61 billion in exports and US $21.19 billion in imports. There was a trade surplus of US $1.41 billion. A study of the composition of exports and imports in 1981 shows that industrial exports make up 92 percent of total exports, agricultural products and processed agricultural products constituted 7 percent of the total. Imports of capital goods accounted for 26 percent of total imports, consumer goods constituted 6 percent, and industrial and agricultural raw materials constituted 68 percent. With respect to trade with various areas of the world, exports to the United States totalled US $8.6 billion in 1981, 38.03 percent of total exports; exports to Japan was US $2.48 billion, 10.96 percent of the total. Imports from the United States amounted to 4.77 billion, 22.51 percent of total imports. Imports from Japan was US $5.92 billion, 27.94 percent of the total.

Shares of the different sectors of the economy in the gross domestic product (GNP) varied according to their respective rates of growth. In 1981, the gross product of the agricultural, fishery and livestock sectors comprised 8.67 percent of GNP (14.12 percent in 1972), manufacturing comprised 44.5 percent of total GDP (40.41 percent in 1972), and services comprised 46.84 percent of total GNP (45.47 percent in 1972).

According to ROC's four-year economic development plan for 1982-1985, an average growth of 8 percent a year in GNP will be seen.

Public investment will be restrained in order to stimulate private sector activity, which includes improving production techniques, modernizing equipment, boosting labor productivity and sharpening the competitiveness of products abroad. Promoting the development of heavy and precision industries will be the major goal. To attain the targeted goal of economic growth, a concerted effort will be made to promote foreign trade. Export goods and services will advance by 10.9 percent per year, while merchandise and services imports will grow by 11.3 percent, with the annual surplus forecast to drop from US $582 million in 1981 to $450 million in 1985.

APPENDIX B

THE TAIWAN INPUT-OUTPUT TABLE

A. THE 1979 TAIWAN INPUT-OUTPUT TABLE*

This study analyzes the impact of an aluminum supply restriction with the use of the 1979 Taiwan input-output table.** Basically, this table is an update of the 1976 Taiwan I-O table, which is fully survey-based. The 1976 Taiwan I-O table was published in three stages of aggregation: 394 x 394 as the basic table, with 99 x 99 and 49 x 49 sectors; and in three forms: the total transactions table, the domestic transactions table, and the import transactions table. Since 1976, the Taiwan industry structure has been changed by the completion of most of the 10 major construction projects.*** Therefore, updating the 1976 I-O table is necessary in order to reflect current conditions.

The updating of the 1976 Taiwan I-O table was based on two approaches. Major sectoral input-output data updates were based on the report of the 1979 manufacturing investigation of Taiwan. Minor sectoral input-output

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*Since 1950, the Council for Economic Planning and Development has published eight Taiwan I-O tables, of which 1961, 1966, 1971 and 1976 I-O tables were compiled fully from survey data; 1964, 1969, 1974, and 1979 I-O tables were generally updated from the previous I-O table.

**The latest Taiwan I-O table (1981) will be published in 1984, and is compiled from the report on the 1981 Industry/Commercial Census of Taiwan.

***The ten major construction projects included: the North-South Freeway, railroad electrification, North Link Railroad, Taoyuan International Airport, Taichung Harbor, Suao Port, the integrated steel mill, the Kaohsiung shipyard, the petrochemical complexes, and the construction of nuclear power plants.

data were updated via sectoral price indices. Because the data for sectoral import transactions were not available, the 1979 I-O table only contained the transactions table at producer's prices aggregated to 49 sectors.

The classification of sectors in the Taiwan I-O table is generally based on national statistical classifications economic activity. The imports of goods and services for intermediate input and final demand in the 1979 I-O table were treated as competitive imports and put in a separate column. Valuation of imports was based on CIF prices. Import taxes were treated as indirect taxes for each sector and incorporated in the final payment. Final demand consisted of personal consumption expenditures, government expenditures, fixed capital formation, inventory change, and total exports. Valuation of exports was based on FOB. The final payment, or gross value-added of a sector was obtained by substracting the total cost of intermediate inputs from the corresponding value of the sectoral product. The 1979 I-O table did not disaggregate the final payment sector. However, we disaggregated it into compensation of employees and other income based on the proportion of each of these two final payment components in the 1976 I-O table. The other income sector included operating surplus, depreciation of capital goods, and net indirect business taxes. The total final payment corresponded to GDP, which was also equal to total final demand minus total imports. The total supply or total demand in this table was equal to the summation of intermediate demand and total final demand. The total domestic gross output was calculated as the total of intermediate inputs plus the final payment, which was also equal to the total supply minus the total imports.

B. FURTHER REFINEMENT OF THE 1979 TAIWAN I-O TABLE

In order to evaluate the impact of an aluminum supply restriction on the whole economy, it is best to separate the aluminum sector from all other sectors in the 1979 I-O table. Initially, the aluminum sector was incorporated into the non-ferrous metals and products sector.* The disaggregation procedures were generally based on the 1976 I-O table. That is, we assumed that the input proportions of aluminum, other metals, and metal products for each sector and the output allocations of aluminum, other metals, and metal products in 1979 are the same as in 1976. Thus, the disaggregation procedures are as follows: (1) first, we aggregated the 1976 I-O table from 99 sectors to 51 sectors including the aluminum sector, other metals sector, and metallic products sector; (2) second, based on the above assumptions and the aggregated 1976 I-O table (51 sectors), we disaggregated the non-ferrous metals and products sector in the original 1979 I-O table into three sectors: aluminum, other metals, and metallic products. The disaggregated 1979 I-O table therefore contained 51 sectors instead of 49 sectors. However, we further aggregated it to be a 34 sector I-O table in order to simplify the computation of the LP model.

Table B.1 presents the full notation of the 1979 Taiwan I-O table. The I-O table generally contains four quadrants. The first quadrant

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*The non-ferrous metals and products sector in the 1979 I-O table included aluminum, other metals, and metallic products subsectors.

Table B.1

NOTATION OF THE 1979 TAIWAN I-O TABLE

		Sectors	Total Intermediate Demand	Final Demand					Total Demand (Q)	Total Imports (M)
		1 2 ... j ... 34		C	G	I	E	S		
S	1		$\sum_j x_{ij}$	C_1	G_1	I_1	E_1	S_1	Q_1	M_1
e	2			.	.	.	.	.	.	.
c	.			.	.	.	.	.	.	.
t	i	$x_{ij} = a_{ij}X_j$		C_i	G_i	I_i	E_i	S_i	Q_i	M_i
o	.			.	.	.	.	.	.	.
r	.			.	.	.	.	.	.	.
s	34			C_{34}	G_{34}	I_{34}	E_{34}	S_{34}	Q_{34}	M_{34}
$U_j = \sum_i x_{ij}$		U_j	$\sum_i \sum_j x_{ij}$							
V_j			$\sum_j V_j$							
X_j			$\sum_j X_j$	C	G	I	E	S	Q	M

Table B.1 (Continued)

$X_j = X_j$ = domestic total gross output in sector i or j

M_i = imports of good i

V_j = final payments (value-added) by sector j

U_j = total intermediate input by sector j

F_i = total final demand for good i

C_i = private consumption expenditures on good i

G_i = government expenditures on good i

I_i = capital formation in good i

E_i = total exports of good i

S_i = net inventory of good i

Q_i = total sectoral demand for good i

a_{ij} = the amount of good i needed to produce one NT$ of good j of the I-O table shows the various elements of final demand for the output of each producing sector. The second quadrant contains inter-sectoral flows or intermediate demand, which shows the flows of sectoral products and services which are both produced and required in the process of current production. The third quadrant corresponds to the final payment or value-added (wages, salaries, profits, capital deprication, and taxes) from the productive sectors. The fourth quadrant represents the value-added which goes directly to the final demand activities. The detailed inter-sectoral flows table in 1979 is presented in Table B.2. Table B.3 is the direct input coefficient (a_{ij}) table. The input coefficient (a_{ij}) is defined as the direct requirement from sector i needed to produce one unit of output in sector j.

The accounting balance equations related to this I-O table are listed as follows:

(B.1) $$\underset{\text{(total supply)}}{Q_i = M_i + X_i} = \underset{\text{(total demand)}}{\sum_j x_{ij} + F_i} = \sum_j a_{ij} X_j + F_i$$

(B.2) $$X_j = \sum_i x_{ij} + V_j = \sum_i a_{ij} X_j + V_j$$

(B.3) $$\sum_i Y_i - \sum_i M_i = \sum_j V_j = \text{GDP}$$

C. APPLICATIONS OF THE I-O MODEL

The I-O model is a linear, intersectoral model of output determination. It can show how each sector in the economy depends on every other sector and how the impact of a change in final demand is distributed among sectors. Because of its general equilibrium character,

TABLE 8.2. THE 1979 TAIWAN INPUT-CUTPUT TABLE

CODE		CODE-1	CODE-2	CODE-3	CCDE-4	CODE-5	CODE-6	CODE-7	CCDE-8
01	AGRICULTURE	3381.4	1733.8	0.00	7.4	0.C0	C.00	0.2	89413
02	LIVESTOCK	1360.4	5451.8	0.00	75.6	0.00	0.00	0.0	39285
03	FORESTRY	269.9	29.3	124.30	148.0	0.00	0.00	0.C	19
04	FISHERIES	0.0	145.9	0.00	3359.7	0.00	C.00	0.0	5444
05	COAL & COAL PRODUCTS	0.0	6.9	0.00	0.0	3252.20	C.00	47.8	251
06	CRUDE OIL & NATURAL GAS	0.0	0.0	0.00	0.0	0.00	17.90	120.8	50
07	OTHER MINERALS	0.6	1.5	1.20	5.1	1.00	2.30	674.2	248
08	MANUFACTURING FOOD	79.0	37627.8	0.00	2171.7	0.20	0.00	3.7	28796
09	TEXTILE & APPAREL ACCESSORIES	89.9	0.8	2.60	475.3	8.30	0.60	59.3	404
10	WOOD & WOOD PRODUCTS	155.8	56.7	0.50	141.6	34.10	0.50	124.3	361
11	PULP PAPER & ALLIED PRODUCTS	9.7	47.9	6.70	5.4	5.90	1.10	16.9	2395
12	RUBBER & RUBBER PRODUCTS	4.6	35.2	0.00	0.0	4.70	0.90	89.5	28
13	PETROCHEMICAL RAW MATERIALS	0.0	0.0	0.00	0.0	0.00	0.00	0.0	92
14	OTHER INDUSTRIAL CHEMICALS	0.8	0.0	0.00	5.5	0.90	C.00	4.2	623
15	CHEMICAL FERTILIZER	4950.2	16.0	0.C0	5.1	0.00	C.00	0.0	159
16	PLASTICS & PLASTIC PRODUCTS	180.7	0.7	0.00	31.4	22.90	C.00	97.8	1829
17	MISC CHEMCIAL HANUUFACTURES	3746.4	1072.6	9.30	150.8	69.40	46.20	75.3	1943
18	PETROLEUM REFINING PRODUCTS	474.9	0.0	83.20	3849.4	52.00	148.30	1826.3	3068
19	CEMENT & CEMENT PRODUCTS	1.1	0.0	1.10	3.2	10.80	0.80	18.9	0
20	MISC NON METAL MINERAL PRODS	0.0	0.0	0.70	24.7	6.20	2.80	13.5	250
21	STEEL & IRON	0.0	0.9	0.00	0.0	8.70	82.20	131.2	56
22	ALUMINUM	0.0	0.0	0.00	0.0	0.00	0.00	0.0	17
23	MISC METALS	0.0	0.0	0.00	0.0	0.C0	73.80	C.0	11
24	METALLIC PRODUCTS	360.4	42.3	7.50	456.7	165.40	185.10	238.8	4981
25	MACHINERY	68.8	0.0	8.30	153.9	80.40	30.90	814.6	766
26	ELECTRICAL APPARATUS & EQUIP	37.1	1.3	0.00	289.0	41.00	4.00	78.1	174
27	TRANSPORT EQUIPMENTS	0.2	0.0	63.70	956.7	25.00	2.90	175.0	199
28	MISC MANUFACTURES	22.2	1.4	5.80	645.7	3.90	2.50	26.8	487
29	CONSTRUCTION	14.5	71.8	133.60	174.2	17.90	1.20	46.0	348
30	ELECTRICITY	126.3	279.9	6.90	166.4	370.60	164.50	186.7	1457
31	GAS & CITY WATER	0.0	180.0	3.90	25.6	1.40	0.60	51.6	233
32	TRANSPORTATION & COMMUNICATIONS	590.6	302.5	182.70	214.9	132.30	8.60	350.8	3139
33	WHOLESALE & RETAIL TRADE	1327.5	4745.3	4.90	451.6	30.20	31.70	111.7	6448
34	MISC SERVICES	13564.2	1576.1	72.60	2172.1	150.80	34.40	622.9	6833
35	TOTAL INTERMEDIATE INPUT	30817.2	53428.4	719.50	16166.7	4496.20	843.80	6006.9	199808
36	COMPENSATION OF EMPLOYEES	42451.3	2268.5	3165.81	14952.3	3208.42	391.52	5949.0	15590
37	OTHER INCOME	22224.0	2202.1	2576.38	9871.9	927.18	4558.75	2914.1	52358
38	TOTAL PRIMARY INPUTS	64675.2	4470.6	5742.19	24824.2	4135.60	4950.27	8863.1	67948
39	DOMESTIC GROSS OUTPUT	95492.5	57899.0	6461.80	40590.7	8631.80	5794.20	14870.1	267750

TABLE B.2. (CONTINUE)

CODE		CODE-9	CODE-10	CODE-11	COCE-12	CODE-13	CODE-14	CODE-15	CCDE-16
01	AGRICULTURE	12294	3.1	360.2	0.0	0.0	0.0	0.00	5
02	LIVESTOCK	1945	9.2	0.0	0.0	0.0	0.0	0.60	0
03	FORESTRY	516	25543.0	785.1	1994.3	0.0	4.6	0.00	66
04	FISHERIES	1	1.3	0.0	0.0	0.0	0.0	0.00	1
05	COAL & COAL PRODUCTS	263	3.2	214.1	17.6	0.0	207.1	50.20	66
06	CRUDE OIL & NATURAL GAS	9	0.3	23.3	2.4	856.2	930.4	1.00	63
07	OTHER MINERALS	51	13.2	56.4	12.4	10.1	1652.8	335.00	12
08	MANUFACTURING FOOD	3003	93.6	1201.6	4.1	0.2	34.0	0.00	5
09	TEXTILE & APPAREL ACCESSORIES	132428	667.4	337.9	2012.0	11.9	30.3	50.10	8559
10	WOOD & WOOD PRODUCTS	409	8572.8	458.6	32.1	4.0	9.8	2.90	582
11	PULP PAPER & ALLIED PRODUCTS	3817	694.7	22743.0	324.9	26.5	53.6	18.10	1727
12	RUBBER & RUBBER PRODUCTS	1280	168.2	104.6	2230.1	5.3	6.7	3.10	1402
13	PETROCHEMICAL RAW MATERIALS	14578	76.1	69.9	1314.7	15915.6	426.8	231.10	21783
14	OTHER INDUSTRIAL CHEMICALS	1898	49.7	941.6	703.0	3284.8	3453.8	1926.10	3084
15	CHEMICAL FERTILIZER	1	73.0	4.1	1.5	29.3	115.0	567.90	270
16	PLASTICS & PLASTIC PRODUCTS	13148	1071.7	437.3	512.3	22.2	69.9	249.50	41538
17	MISC CHEMCIAL MANUUFACTURES	5169	1260.0	2066.8	1C97.2	257.6	66.6	15.50	4795
18	PETROLEUM REFINING PRODUCTS	2661	187.8	1433.5	194.4	6977.7	778.6	102.00	1095
19	CEMENT & CEMENT PRODUCTS	7	0.0	0.0	0.0	0.0	3.3	1.10	0
20	MISC NON METAL MINERAL PRODS	41	169.5	140.3	33.8	14.7	112.9	10.60	199
21	STEEL & IRON	86	181.3	34.8	52.9	159.5	50.0	27.50	285
22	ALUMINUM	6	4.3	54.5	0.0	0.0	0.9	0.00	117
23	MISC METALS	37	17.9	2.5	0.6	66.6	338.5	0.92	28
24	METALLIC PRODUCTS	1012	571.4	302.2	230.7	439.8	191.3	48.78	1468
25	MACHINERY	2871	325.3	527.1	145.1	294.2	369.7	460.70	862
26	ELECTRICAL APPARATUS & EQUIP	353	136.9	83.9	42.5	36.1	49.6	17.70	178
27	TRANSPORT EQUIPMENTS	305	92.9	53.4	24.3	15.7	38.3	6.10	106
28	MISC MANUFACTURES	780	82.7	130.5	29.7	16.8	9.5	4.00	547
29	CONSTRUCTION	395	124.8	126.7	38.4	52.6	35.7	16.70	245
30	ELECTRICITY	7471	687.1	1533.3	407.9	498.9	1535.6	400.40	1936
31	GAS & CITY WATER	227	45.0	17.5	21.5	32.9	86.4	10.10	52
32	TRANSPORTATION & COMMUNICATIONS	3561	1472.1	829.3	307.2	257.1	213.4	73.70	1749
33	WHOLESALE & RETAIL TRADE	4588	1994.6	1705.9	655.5	355.2	269.9	124.30	3170
34	MISC SERVICES	13199	2400.1	3270.1	1300.9	3070.0	881.1	152.80	5066
35	TOTAL INTERMEDIATE INPUT	228410	46794.2	40050.0	13744.0	32711.5	12025.0	4908.50	101060
36	COMPENSATION OF EMPLOYEES	51590	11453.7	11270.8	4341.1	1151.7	1780.4	577.01	17860
37	OTHER INCOME	38927	11799.1	10303.0	4246.9	9269.8	3618.9	713.79	22633
38	TOTAL PRIMARY INPUTS	90517	23252.7	21573.8	8588.0	10421.5	5399.3	1290.80	40493
39	DOMESTIC GROSS OUTPUT	318927	70046.7	61623.8	22332.0	43133.0	17425.3	6199.30	141554

TABLE B.2. (CONTINUE)

CODE		CODE-17	CODE-18	CODE-19	CODE-20	CODE-21	CODE-22	CODE-23	CODE-24
01	AGRICULTURE	41.6	0	0.0	1.4	0	0.00	0.00	0.0
02	LIVESTOCK	30.2	0	0.0	0.0	0	0.00	0.00	0.0
03	FORESTRY	47.5	0	0.4	4.1	2	0.00	0.60	0.0
04	FISHERIES	0.0	0	0.0	16.9	0	0.00	0.00	0.0
05	COAL & COAL PRODUCTS	46.4	13	1031.7	931.9	4447	4.75	39.04	253.2
06	CRUDE OIL & NATURAL GAS	18.2	75453	0.0	1612.0	9	0.00	0.41	6.3
07	OTHER MINERALS	293.0	51	1943.9	3818.3	2309	112.70	726.79	30.6
08	MANUFACTURING FOOD	628.0	0	0.0	0.9	0	1.21	0.00	1.1
09	TEXTILE & APPAREL ACCESSORIES	338.3	1	5.3	119.4	21	5.86	1.71	132.8
10	WOOD & WOOD PRODUCTS	301.2	17	35.4	182.4	39	38.38	1.60	335.8
11	PULP PAPER & ALLIED PRODUCTS	996.7	23	1299.9	571.1	122	54.45	7.10	490.3
12	RUBBER & RUBBER PRODUCTS	98.4	0	13.2	35.6	39	3.02	1.63	51.2
13	PETROCHEMICAL RAW MATERIALS	2358.5	1043	0.0	10.7	40	2.35	0.20	10.9
14	OTHER INDUSTRIAL CHEMICALS	3432.2	26	5.8	775.6	486	323.72	3.54	1020.4
15	CHEMICAL FERTILIZER	41.7	0	0.0	0.0	0	0.00	0.00	0.1
16	PLASTICS & PLASTIC PRODUCTS	1841.6	0	4.3	255.7	21	4.18	3.54	478.6
17	MISC CHEMCIAL MANUUFACTURES	10126.9	939	7.9	486.3	88	17.41	16.51	925.6
18	PETROLEUM REFINING PRODUCTS	1102.4	4944	2688.5	1115.0	1103	309.53	54.21	363.3
19	CEMENT & CEMENT PRODUCTS	0.6	0	2228.1	404.0	3	0.97	0.46	7.5
20	MISC NON METAL MINERAL PRODS	233.2	47	234.3	739.7	1803	44.12	18.23	185.1
21	STEEL & IRON	89.2	513	612.0	59.9	50664	33.07	486.93	15439.8
22	ALUMINUM	61.4	0	0.0	0.4	3	3388.52	10.27	2623.0
23	MISC METALS	113.3	306	8.4	31.0	330	56.05	1771.58	4505.2
24	METALLIC PRODUCTS	706.4	849	447.6	30.4	1950	22.12	284.99	6482.3
25	MACHINERY	224.3	245	613.4	366.1	502	50.51	71.86	545.5
26	ELECTRICAL APPARATUS & EQUIP	42.1	72	63.0	63.0	79	14.39	140.04	177.6
27	TRANSPORT EQUIPMENTS	69.6	51	100.7	50.0	88	3.31	3.31	90.5
28	MISC MANUFACTURES	29.1	48	26.4	38.7	35	1.75	4.59	80.5
29	CONSTRUCTION	77.6	28	22.1	116.1	61	9.44	1.76	105.7
30	ELECTRICITY	801.6	700	1470.3	798.8	3431	903.01	74.04	1423.2
31	GAS & CITY WATER	98.7	16	8.0	53.7	68	7.62	0.89	98.2
32	TRANSPORTATION & COMMUNICATIONS	485.5	222	704.8	767.3	1525	82.77	79.34	762.2
33	WHOLESALE & RETAIL TRADE	1562.7	288	417.9	706.8	5172	288.97	274.34	2275.6
34	MISC SERVICES	2674.7	1384	647.8	1237.7	6719	249.19	447.82	2344.4
35	TOTAL INTERMEDIATE INPUT	29012.8	87276	14641.1	15401.0	81159	6033.37	4527.33	41246.5
36	COMPENSATION OF EMPLOYEES	4739.6	2038	2751.9	6969.4	9722	607.71	499.53	12970.9
37	OTHER INCOME	6870.6	14767	11046.8	5282.7	13965	492.58	1130.98	9862.0
38	TOTAL PRIMARY INPUTS	11610.2	16805	13798.7	12252.1	23688	1100.29	1630.51	22832.9
39	DOMESTIC GROSS OUTPUT	40623.0	104082	28439.8	27653.1	104847	6860.24	6575.32	63936.7

TABLE B.2. (CONTINUE)

CODE		CODE-25	CODE-26	CODE-27	CODE-28	CODE-29	CODE-30	CODE-31	CODE-32
01	AGRICULTURE	0.0	0	0.0	113.9	68	0.0	0.0	0
02	LIVESTOCK	0.0	0	0.0	69.4	0	0.0	0.0	0
03	FORESTRY	0.1	0	24.9	282.3	281	0.0	0.0	0
04	FISHERIES	0.0	0	0.0	17.0	0	0.0	0.0	0
05	COAL & COAL PRODUCTS	176.2	131	22.9	11.0	0	2479.6	29.2	25
06	CRUDE OIL & NATURAL GAS	13.2	123	0.0	76.1	0	1248.6	461.1	0
07	OTHER MINERALS	7.7	43	8.2	279.9	6779	0.0	0.0	0
08	MANUFACTURING FOOD	0.3	3	0.0	263.8	0	0.0	0.4	0
09	TEXTILE & APPAREL ACCESSORIES	67.2	562	89.4	4124.3	219	18.8	9.6	107
10	WOOD & WOOD PRODUCTS	268.0	1760	796.7	1994.7	11104	22.3	0.0	114
11	PULP PAPER & ALLIED PRODUCTS	167.9	2058	344.0	1670.3	323	6.0	19.0	574
12	RUBBER & RUBBER PRODUCTS	170.4	560	2112.3	191.3	117	0.0	0.3	1913
13	PETROCHEMICAL RAW MATERIALS	16.8	106	27.8	12.8	0	0.0	0.0	0
14	OTHER INDUSTRIAL CHEMICALS	50.4	780	261.8	213.0	16	0.1	31.8	42
15	CHEMICAL FERTILIZER	0.0	8	0.2	8.6	0	0.0	0.0	0
16	PLASTICS & PLASTIC PRODUCTS	256.3	7675	1081.4	4893.1	4020	0.9	21.3	0
17	MISC CHEMCIAL MANUUFACTURES	146.2	1332	805.0	735.8	1933	1.5	31.5	119
18	PETROLEUM REFINING PRODUCTS	261.2	648	562.8	78.1	1479	19633.1	5029.2	19128
19	CEMENT & CEMENT PRODUCTS	3.8	0	0.0	3.8	23702	0.0	0.0	4
20	MISC NON METAL MINERAL PRODS	213.4	2030	462.7	1396.0	10099	0.6	0.1	0
21	STEEL & IRON	16607.7	8145	9070.0	1192.6	21304	7.6	64.5	91
22	ALUMINUM	299.2	1721	1096.0	166.4	228	0.0	0.0	0
23	MISC METALS	955.3	4317	338.3	653.5	34	0.0	12.9	0
24	METALLIC PRODUCTS	1829.2	10318	2382.8	3358.0	7182	15.8	2.4	114
25	MACHINERY	5989.7	1037	4759.0	70.4	560	6.5	136.4	113
26	ELECTRICAL APPARATUS & EQUIP	1344.0	77028	1322.3	809.8	6398	295.1	1.3	582
27	TRANSPORT EQUIPMENTS	99.0	125	27884.0	52.6	171	51.3	97.3	6521
28	MISC MANUFACTURES	95.5	722	217.3	4754.2	156	78.8	18.1	180
29	CONSTRUCTION	78.6	424	169.3	133.9	157	63.3	32.6	513
30	ELECTRICITY	767.4	1686	926.9	715.6	559	3962.4	364.9	1187
31	GAS & CITY WATER	23.3	200	78.7	68.1	112	16.0	570.3	156
32	TRANSPORTATION & COMMUNICATIONS	751.7	2288	1142.9	792.1	5915	474.0	44.1	7515
33	WHOLESALE & RETAIL TRADE	1956.0	3635	4909.0	1940.8	7475	105.7	62.0	549
34	MISC SERVICES	2501.9	9444	4969.2	2221.3	6153	2309.8	518.5	10278
35	TOTAL INTERMEDIATE INPUT	35117.6	138907	65865.8	33364.5	116546	30797.8	7558.8	49825
36	COMPENSATION OF EMPLOYEES	11185.5	26956	14011.8	13719.0	43458	3770.0	1111.6	35884
37	OTHER INCOME	8640.5	30545	18709.6	9443.9	23755	21056.4	2473.7	32953
38	TOTAL PRIMARY INPUTS	19826.0	57501	32721.4	23162.9	67213	24826.4	3585.3	68837
39	DOMESTIC GROSS OUTPUT	54943.6	196408	98587.2	56527.5	183759	55624.4	11144.1	118662

TABLE B.2. (CONTINUE)

CODE		CODE-33	CODE-34	INTER-MEDIATE DEMAND	PERSONAL CONSUMP. EXPEND.	GOVT. CONSUMP. EXPEND.	CAPITAL FORMATION	TOTAL EXPORT	INVENTORY CHANGE
01	AGRICULTURE	152	1550	109125	27736	21	2262	3182	960.6
02	LIVESTOCK	0	1653	49880	8666	0	878	815	86.6
03	FORESTRY	0	54	30196	444	3	1225	906	99.3
04	FISHERIES	0	129	9115	18969	0	0	15967	-87.4
05	COAL & COAL PRODUCTS	0	135	14156	43	1	0	62	271.6
06	CRUDE OIL & NATURAL GAS	0	156	81251	578	0	0	0	2661.7
07	OTHER MINERALS	0	1974	21453	325	360	0	205	523.3
08	MANUFACTURING FOOD	34	4374	78327	158488	120	0	40296	12647.1
09	TEXTILE & APPAREL ACCESSORIES	461	3215	154637	23874	2447	417	144749	10218.1
10	WOOD & WOOD PRODUCTS	714	571	29243	2335	170	2006	35195	2923.2
11	PULP PAPER & ALLIED PRODUCTS	2700	8041	51355	7282	3080	189	3543	4086.0
12	RUBBER & RUBBER PRODUCTS	35	1052	11757	3002	1006	0	9349	577.1
13	PETROCHEMICAL RAW MATERIALS	0	1687	59802	0	0	0	1519	3479.2
14	OTHER INDUSTRIAL CHEMICALS	0	537	23981	0	662	0	1440	1432.7
15	CHEMICAL FERTILIZER	0	0	6252	0	5	0	286	159.1
16	PLASTICS & PLASTIC PRODUCTS	2289	5884	87942	6861	258	50	49721	6567.1
17	MISC CHEMCIAL MANUUFACTURES	14	3795	43361	13216	1027	0	3759	3041.0
18	PETROLEUM REFINING PRODUCTS	2957	1675	86064	9952	6612	0	14025	852.6
19	CEMENT & CEMENT PRODUCTS	0	962	27367	0	522	0	468	170.1
20	MISC NON METAL MINERAL PRODS	3	1650	20179	1126	190	397	8571	953.8
21	STEEL & IRON	0	4031	129568	0	762	0	17033	5425.7
22	ALUMINUM	0	73	9870	0	87	0	366	99.1
23	MISC METALS	0	246	14969	0	3	0	1528	112.7
24	METALLIC PRODUCTS	8	1070	47150	1375	1452	1362	23339	189.6
25	MACHINERY	248	4093	27410	23	237	58948	17480	3045.7
26	ELECTRICAL APPARATUS & EQUIP	169	3270	93395	16933	502	35798	120370	6324.9
27	TRANSPORT EQUIPMENTS	1110	1546	40177	27031	1863	37435	0	4017.1
28	MISC MANUFACTURES	490	3149	12919	7013	986	8555	47787	1320.7
29	CONSTRUCTION	893	9327	14055	176	575	168987	1	0.0
30	ELECTRICITY	2051	4911	43961	9913	1952	0	1	0.0
31	GAS & CITY WATER	671	1355	4591	6249	393	0	41	0.0
32	TRANSPORTATION & COMMUNICATIONS	9435	7860	54230	50341	9711	369	23525	522.0
33	WHOLESALE & RETAIL TRADE	815	3588	62035	77683	3896	9377	33171	3780.1
34	MISC SERVICES	24071	29915	162453	154562	120139	0	26035	0.0
35	TOTAL INTERMEDIATE INPUT	49319	113528	1712115	634194	159042	328253	644627	76460.4
36	COMPENSATION OF EMPLOYEES	69931	168423	616752	0	0	0	0	0.0
37	OTHER INCOME	70692	128015	608846	6956	601	14246	246	5763.7
38	TOTAL PRIMARY INPUTS	140623	296438	1225598	6956	601	14246	246	5763.7
39	DOMESTIC GROSS OUTPUT	189942	409967	2937713	641151	0	0	0	0.0

TABLE B.2. (CONTINUE)

CODE		TOTAL FINAL DEMAND	TOTAL DEMAND	TOTAL IMPORT
01	AGRICULTURE	34161	143286	47794
02	LIVESTOCK	10445	60325	2426
03	FORESTRY	2677	32874	26412
04	FISHERIES	34848	43963	2973
05	COAL & COAL PRODUCTS	382	14538	5906
06	CRUDE OIL & NATURAL GAS	3240	84491	78696
07	OTHER MINERALS	1413	22866	7996
08	MANUFACTURING FOOD	211551	289878	22127
09	TEXTILE & APPAREL ACCESSORIES	181706	336343	17416
10	WOOD & WOOD PRODUCTS	42628	71871	1824
11	PULP PAPER & ALLIED PRODUCTS	18180	69534	7910
12	RUBBER & RUBBER PRODUCTS	13934	25691	3359
13	PETROCHEMICAL RAW MATERIALS	4998	64801	21668
14	OTHER INDUSTRIAL CHEMICALS	3534	27515	10089
15	CHEMICAL FERTILIZER	451	6703	503
16	PLASTICS & PLASTIC PRODUCTS	63457	151399	9846
17	MISC CHEMCIAL MANUUFACTURES	21043	64403	23780
18	PETROLEUM REFINING PRODUCTS	31441	117505	13424
19	CEMENT & CEMENT PRODUCTS	1159	28526	86
20	MISC NON METAL MINERAL PRODS	11236	31415	3762
21	STEEL & IRON	23221	152790	47943
22	ALUMINUM	674	10554	3694
23	MISC METALS	1631	16761	10185
24	METALLIC PRODUCTS	27516	74371	10435
25	MACHINERY	79733	107143	52200
26	ELECTRICAL APPARATUS & EQUIP	161171	254566	58158
27	TRANSPORT EQUIPMENTS	89102	129279	30692
28	MISC MANUFACTURES	65662	78581	22053
29	CONSTRUCTION	169738	183793	34
30	ELECTRICITY	11867	55828	204
31	GAS & CITY WATER	6684	11275	131
32	TRANSPORTATION & COMMUNICATIONS	84467	138697	20035
33	WHOLESALE & RETAIL TRADE	127907	189942	0
34	MISC SERVICES	300736	463189	53223
35	TOTAL INTERMEDIATE INPUT	1842581	3554695	616983
36	COMPENSATION OF EMPLOYEES	0	616752	0
37	OTHER INCOME	27813	636659	0
38	TOTAL PRIMARY INPUTS	27813	1253411	0
39	DOMESTIC GROSS OUTPUT	0	2937713	0

TABLE B.3. THE DIRECT INPUT COEFFICIENT TABLE

CODE		CODE-1	CODE-2	CCDE-3	CODE-4	CCDE-5	CODE-6	CODE-7
01	AGRICULTURE	0.035410	0.029945	0.0000000	0.0001805	0.CC0000	0.00CC000	0.0C0013
02	LIVESTOCK	0.014246	0.094161	C.0G00000	0.0018443	0.C00000	0.00C0000	C.C00000
03	FORESTRY	0.002826	0.000506	0.0192361	0.0036106	0.0000C0	0.00000C0	0.00C000
04	FISHERIES	0.000000	0.002520	0.0000000	0.0819625	0.0C0CC0	0.CCC0000	0.0C0000
05	COAL & COAL PRODUCTS	0.000000	0.000119	0.0000000	0.0000000	0.376770	0.0000000	0.003215
06	CRUDE OIL & NATURAL GAS	0.000000	0.000000	0.0000000	0.0000000	0.0000C0	0.0030893	0.008124
07	OTHER MINERALS	0.000006	0.000026	0.0G01857	0.0001244	0.0C0116	0.0003969	0.045339
08	MANUFACTURING FOOD	0.000827	0.649887	0.0G00000	0.0529803	0.000023	0.C000000	0.000249
09	TEXTILE & APPAREL ACCESSORIES	0.000941	0.000014	0.0004024	0.0115953	0.000962	0.C001036	0.003988
10	WOOD & WOOD PRODUCTS	0.001632	0.000979	0.0000774	0.0034544	0.003951	0.C0C0863	0.008359
11	PULP PAPER & ALLIED PRODUCTS	0.000102	0.000827	0.0010369	0.0001317	0.000684	0.0001898	0.001137
12	RUBBER & RUBBER PRODUCTS	0.000048	0.000608	0.0000000	0.0000000	0.000544	C.0001553	C.CC6019
13	PETROCHEMICAL RAW MATERIALS	0.000000	0.000000	0.0C00000	0.0000000	0.000000	0.0000000	0.0C00C0
14	OTHER INDUSTRIAL CHEMICALS	0.000008	0.000000	0.0C00000	0.0001342	0.000104	0.0000000	C.000282
15	CHEMICAL FERTILIZER	0.051839	0.000276	0.0C00000	0.0001244	0.000000	0.0000000	0.0C0000
16	PLASTICS & PLASTIC PRODUCTS	0.001892	0.000012	0.0000000	0.0007660	0.002653	0.0000000	0.006577
17	MISC CHEMCIAL MANUUFACTURES	0.039232	0.018525	0.0014392	0.0036789	0.008040	0.0079735	0.005064
18	PETROLEUM REFINING PRODUCTS	0.004973	0.000000	0.0128757	0.0939091	0.006024	0.C255946	0.122817
19	CEMENT & CEMENT PRODUCTS	0.000012	0.000000	0.0001702	0.0000781	0.001251	0.0001381	0.001271
20	MISC NON METAL MINERAL PRODS	0.000000	0.000000	0.0001083	0.0006026	0.000718	0.0004832	0.000908
21	STEEL & IRON	0.000000	0.000016	0.0000000	0.0000000	0.001008	0.0141866	0.008823
22	ALUMINUM	0.000000	0.000000	0.0000000	0.0000000	0.000000	0.0000000	0.000000
23	MISC METALS	0.000000	0.000000	0.0000000	0.0000000	0.000000	0.0127362	0.0C0000
24	METALLIC PRODUCTS	0.003774	0.000731	0.0011607	0.0111416	0.019162	0.0319464	0.016059
25	MACHINERY	0.000720	0.000000	0.0012845	0.0037545	0.009314	0.0053329	0.054781
26	ELECTRICAL APPARATUS & EQUIP	0.000389	0.000022	0.0000000	0.0070504	0.004750	0.0006903	0.005252
27	TRANSPORT EQUIPMENTS	0.000002	0.000000	0.0098579	0.0233394	0.002896	0.0005005	0.011769
28	MISC MANUFACTURES	0.000232	0.000024	0.0008976	0.0157524	0.000452	0.C004315	0.001802
29	CONSTRUCTION	0.000152	0.001240	0.0206754	0.0042497	0.002074	0.0002071	0.003093
30	ELECTRICITY	0.001323	0.004834	0.0010678	0.0040595	0.042934	0.0283905	0.012555
31	GAS & CITY WATER	0.000000	0.003109	0.CC06035	0.0006245	0.000162	0.0001036	0.003470
32	TRANSPORTATION & COMMUNICATIONS	0.005185	0.005225	0.0282739	0.0052427	0.015327	0.0014842	0.023591
33	WHOLESALE & RETAIL TRADE	0.013902	0.081958	0.0007583	0.0110171	0.003499	0.0054710	C.007512
34	MISC SERVICES	0.142045	0.027222	0.0112353	0.0529901	0.017470	0.0059370	0.041889

TABLE B.3. (CONTINUE)

CODE		CODE-8	CODE-9	CODE-10	CODE-11	CODE-12	CODE-13	CODE-14
01	AGRICULTURE	0.333941	0.038547	0.000044	0.005845	0.0000000	0.000000	0.000000
02	LIVESTOCK	0.146722	0.006098	0.000131	0.000000	0.0000000	0.000000	0.000000
03	FORESTRY	0.000072	0.001618	0.364657	0.012740	0.0893023	0.000000	0.000264
04	FISHERIES	0.020333	0.000002	0.000019	0.000000	0.0000000	0.000000	0.000000
05	COAL & COAL PRODUCTS	0.000937	0.000825	0.000046	0.003474	0.0007881	0.000000	0.011885
06	CRUDE OIL & NATURAL GAS	0.000186	0.000030	0.000004	0.000378	0.0001075	0.019850	0.053394
07	OTHER MINERALS	0.000927	0.000159	0.000188	0.000915	0.0005553	0.000234	0.094851
08	MANUFACTURING FOOD	0.107549	0.009418	0.001336	0.019499	0.0001836	0.000005	0.001951
09	TEXTILE & APPAREL ACCESSORIES	0.001509	0.415229	0.009528	0.005483	0.0900949	0.000276	0.001739
10	WOOD & WOOD PRODUCTS	0.001348	0.001282	0.122387	0.007442	0.0014374	0.000093	0.000562
11	PULP PAPER & ALLIED PRODUCTS	0.008946	0.011967	0.009918	0.369062	0.0145486	0.000614	0.003076
12	RUBBER & RUBBER PRODUCTS	0.000105	0.004014	0.002401	0.001697	0.0998612	0.000123	0.000384
13	PETROCHEMICAL RAW MATERIALS	0.000344	0.045711	0.001086	0.001134	0.0588707	0.368989	0.024493
14	OTHER INDUSTRIAL CHEMICALS	0.002328	0.005952	0.000710	0.015280	0.0314795	0.076155	0.198206
15	CHEMICAL FERTILIZER	0.000594	0.000002	0.001042	0.000067	0.0000672	0.000679	0.006600
16	PLASTICS & PLASTIC PRODUCTS	0.006830	0.041225	0.015300	0.007096	0.0229402	0.000515	0.004011
17	MISC CHEMCIAL MANUUFACTURES	0.007258	0.016209	0.017988	0.033539	0.0491313	0.005972	0.003822
18	PETROLEUM REFINING PRODUCTS	0.011458	0.008343	0.002681	0.023262	0.0087050	0.161772	0.044682
19	CEMENT & CEMENT PRODUCTS	0.000000	0.000021	0.000000	0.000000	0.0000000	0.000000	0.000189
20	MISC NON METAL MINERAL PRODS	0.000934	0.000129	0.002420	0.002277	0.0015135	0.000341	0.006479
21	STEEL & IRON	0.000210	0.000270	0.002588	0.000565	0.0023688	0.003698	0.002869
22	ALUMINUM	0.000064	0.000019	0.000061	0.000884	0.0000000	0.000000	0.000051
23	MISC METALS	0.000041	0.000116	0.000256	0.000041	0.0000253	0.001545	0.019423
24	METALLIC PRODUCTS	0.018603	0.003175	0.008158	0.004904	0.0103320	0.010195	0.010976
25	MACHINERY	0.002861	0.009001	0.004644	0.008554	0.0064974	0.006821	0.021216
26	ELECTRICAL APPARATUS & EQUIP	0.000651	0.001108	0.001954	0.001361	0.0019031	0.000837	0.002646
27	TRANSPORT EQUIPMENTS	0.000744	0.000956	0.001326	0.000867	0.0010881	0.000364	0.002198
28	MISC MANUFACTURES	0.001818	0.002446	0.001181	0.002118	0.0013299	0.000389	0.000545
29	CONSTRUCTION	0.001299	0.001238	0.001782	0.002056	0.0017195	0.001219	0.002049
30	ELECTRICITY	0.005443	0.023424	0.009809	0.024882	0.0182653	0.011567	0.088125
31	GAS & CITY WATER	0.000870	0.000713	0.000642	0.000284	0.0009627	0.000763	0.004958
32	TRANSPORTATION & COMMUNICATIONS	0.011724	0.011166	0.021016	0.013457	0.0137560	0.005961	0.012247
33	WHOLESALE & RETAIL TRADE	0.024081	0.014386	0.028475	0.027682	0.0293525	0.008235	0.015489
34	MISC SERVICES	0.025519	0.041387	0.034264	0.053066	0.0582527	0.071175	0.050564

TABLE B.3. (CONTINUE)

CODE		CODE-15	CODE-16	CODE-17	CODE-18	CODE-19	CODE-20	CODE-21
01	AGRICULTURE	0.000000	0.000037	0.001024	0.000000	0.0000000	0.000051	0.000000
02	LIVESTOCK	0.000097	0.000000	0.000743	0.000000	0.0000000	0.000000	0.000000
03	FORESTRY	0.000000	0.000463	0.001169	0.000000	0.0000141	0.000148	0.000014
04	FISHERIES	0.000000	0.000005	0.000000	0.000000	0.0000000	0.000611	0.000000
05	COAL & COAL PRODUCTS	0.008098	0.000469	0.001142	0.000121	0.0362766	0.033700	0.042416
06	CRUDE OIL & NATURAL GAS	0.000161	0.000442	0.000448	0.724942	0.0000000	0.058294	0.000085
07	OTHER MINERALS	0.054038	0.000087	0.007213	0.000486	0.0683514	0.138079	0.022018
08	MANUFACTURING FOOD	0.000000	0.000035	0.015459	0.000000	0.0000000	0.000033	0.000003
09	TEXTILE & APPAREL ACCESSORIES	0.008082	0.060466	0.008328	0.000009	0.0001864	0.004318	0.000203
10	WOOD & WOOD PRODUCTS	0.000468	0.004111	0.007415	0.000167	0.0012447	0.006596	0.000374
11	PULP PAPER & ALLIED PRODUCTS	0.002920	0.012200	0.024535	0.000223	0.0457071	0.020652	0.001160
12	RUBBER & RUBBER PRODUCTS	0.000500	0.009906	0.002422	0.000001	0.0004641	0.001287	0.000368
13	PETROCHEMICAL RAW MATERIALS	0.037278	0.153882	0.058058	0.010016	0.0000000	0.000387	0.000380
14	OTHER INDUSTRIAL CHEMICALS	0.310696	0.021785	0.084489	0.000249	0.0002039	0.028047	0.004637
15	CHEMICAL FERTILIZER	0.091607	0.001910	0.001027	0.000000	0.0000000	0.000000	0.000000
16	PLASTICS & PLASTIC PRODUCTS	0.040246	0.293440	0.045334	0.000004	0.0001512	0.009247	0.000201
17	MISC CHEMCIAL MANUUFACTURES	0.002500	0.033871	0.249290	0.009017	0.0002778	0.017586	0.000839
18	PETROLEUM REFINING PRODUCTS	0.016453	0.007737	0.027137	0.047504	0.0945330	0.040321	0.010520
19	CEMENT & CEMENT PRODUCTS	0.000177	0.000000	0.000015	0.000000	0.0783444	0.014610	0.000029
20	MISC NON METAL MINERAL PRODS	0.001710	0.001409	0.005741	0.000449	0.0082385	0.026749	0.017198
21	STEEL & IRON	0.004436	0.002016	0.002196	0.004926	0.0215191	0.002166	0.483221
22	ALUMINUM	0.000000	0.000824	0.001512	0.000000	0.0000000	0.000016	0.000032
23	MISC METALS	0.000149	0.000198	0.002788	0.002937	0.0002949	0.001122	0.003146
24	METALLIC PRODUCTS	0.007868	0.010373	0.017390	0.008162	0.0157390	0.001101	0.018596
25	MACHINERY	0.074315	0.006087	0.005522	0.002353	0.0215684	0.013239	0.004792
26	ELECTRICAL APPARATUS & EQUIP	0.002855	0.001260	0.001036	0.000692	0.0022152	0.002278	0.000754
27	TRANSPORT EQUIPMENTS	0.000984	0.000750	0.001713	0.000486	0.0035408	0.001808	0.000837
28	MISC MANUFACTURES	0.000645	0.003867	0.000716	0.000456	0.0009283	0.001399	0.000331
29	CONSTRUCTION	0.002694	0.001729	0.001910	0.000265	0.0007771	0.004198	0.000586
30	ELECTRICITY	0.064588	0.013678	0.019733	0.006724	0.0516987	0.028886	0.032720
31	GAS & CITY WATER	0.001629	0.000365	0.002430	0.000156	0.0002813	0.001942	0.000651
32	TRANSPORTATION & COMMUNICATIONS	0.011888	0.012356	0.011951	0.002133	0.0247822	0.027747	0.014544
33	WHOLESALE & RETAIL TRADE	0.020051	0.022392	0.038468	0.002762	0.0146942	0.025560	0.049331
34	MISC SERVICES	0.024648	0.035786	0.065842	0.013296	0.0227779	0.044758	0.064088

TABLE B.3. (CONTINUE)

CODE		CODE-22	CODE-23	CODE-24	CODE-25	CODE-26	CODE-27	CODE-28
01	AGRICULTURE	0.000000	0.000000	0.000000	0.000000	0.000001	0.000000	0.0020149
02	LIVESTOCK	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0012277
03	FORESTRY	0.000000	0.000091	0.000000	0.000002	0.000000	0.000253	0.0049940
04	FISHERIES	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0003007
05	COAL & COAL PRODUCTS	0.000692	0.005937	0.003960	0.003207	0.000667	0.000232	0.0001946
06	CRUDE OIL & NATURAL GAS	0.000000	0.000062	0.000098	0.000240	0.000624	0.000000	0.0013462
07	OTHER MINERALS	0.016427	0.110533	0.000479	0.000140	0.000218	0.000083	0.0049516
08	MANUFACTURING FOOD	0.000176	0.000000	0.000017	0.000005	0.000015	0.000000	0.0046668
09	TEXTILE & APPAREL ACCESSORIES	0.000854	0.000260	0.002077	0.001223	0.002864	0.000907	0.0729609
10	WOOD & WOOD PRODUCTS	0.005595	0.000244	0.005252	0.004878	0.008963	0.008081	0.0352872
11	PULP PAPER & ALLIED PRODUCTS	0.007937	0.001080	0.007669	0.003056	0.010477	0.003489	0.0295484
12	RUBBER & RUBBER PRODUCTS	0.000441	0.000248	0.000802	0.003101	0.002853	0.021426	0.0033842
13	PETROCHEMICAL RAW MATERIALS	0.000343	0.000030	0.000171	0.000306	0.000539	0.000282	0.0002264
14	OTHER INDUSTRIAL CHEMICALS	0.047188	0.000538	0.015960	0.000917	0.003969	0.002656	0.0037681
15	CHEMICAL FERTILIZER	0.000000	0.000000	0.000002	0.000000	0.000038	0.000002	0.0001521
16	PLASTICS & PLASTIC PRODUCTS	0.000609	0.000538	0.007485	0.004665	0.039077	0.010969	0.0865614
17	MISC CHEMCIAL MANUUFACTURES	0.002538	0.002511	0.014476	0.002661	0.006780	0.008165	0.0130167
18	PETROLEUM REFINING PRODUCTS	0.045119	0.008244	0.005682	0.004754	0.003301	0.005709	0.0013816
19	CEMENT & CEMENT PRODUCTS	0.000141	0.000071	0.000117	0.000069	0.000000	0.000000	0.0000672
20	MISC NON METAL MINERAL PRODS	0.006431	0.002773	0.002894	0.003884	0.010335	0.004693	0.0246959
21	STEEL & IRON	0.004821	0.074054	0.241486	0.302268	0.041469	0.092000	0.0210977
22	ALUMINUM	0.493936	0.001562	0.041026	0.005446	0.008760	0.011117	0.0029438
23	MISC METALS	0.008171	0.269429	0.070464	0.017386	0.021980	0.003432	0.0115615
24	METALLIC PRODUCTS	0.003224	0.043342	0.101386	0.033292	0.052535	0.024170	0.0594039
25	MACHINERY	0.007363	0.010929	0.008532	0.109015	0.005282	0.048272	0.0012454
26	ELECTRICAL APPARATUS & EQUIP	0.002098	0.021298	0.002777	0.024461	0.392184	0.013412	0.0143258
27	TRANSPORT EQUIPMENTS	0.000482	0.000503	0.001415	0.001802	0.000634	0.282836	0.0009305
28	MISC MANUFACTURES	0.000256	0.000698	0.001258	0.001738	0.003673	0.002204	0.0841042
29	CONSTRUCTION	0.001376	0.000268	0.001653	0.001431	0.002161	0.001717	0.0023688
30	ELECTRICITY	0.131629	0.011260	0.022259	0.013967	0.008583	0.009402	0.0126593
31	GAS & CITY WATER	0.001110	0.000135	0.001536	0.000424	0.001019	0.000798	0.0012047
32	TRANSPORTATION & COMMUNICATIONS	0.012065	0.012067	0.011921	0.013681	0.011647	0.011593	0.0140126
33	WHOLESALE & RETAIL TRADE	0.042122	0.041723	0.035591	0.035600	0.018505	0.049793	0.0343337
34	MISC SERVICES	0.036324	0.068107	0.036667	0.045536	0.048082	0.050404	0.0392959

TABLE B.3. (CONTINUE)

CODE		CODE-29	CODE-30	CODE-31	CODE-32	CODE-33	CODE-34
01	AGRICULTURE	0.000370	0.000000	0.000000	0.000000	0.000799	0.0037820
02	LIVESTOCK	0.000000	0.000000	0.000000	0.000000	0.000000	0.0040318
03	FORESTRY	0.001528	0.000000	0.000000	0.000000	0.000001	0.0001329
04	FISHERIES	0.000000	0.000000	0.000000	0.000000	0.000000	0.0003142
05	COAL & COAL PRODUCTS	0.000000	0.044578	0.002620	0.000208	0.000000	0.0003286
06	CRUDE OIL & NATURAL GAS	0.000000	0.022447	0.041376	0.000000	0.000000	0.0003803
07	OTHER MINERALS	0.036893	0.000000	0.000000	0.000000	0.000000	0.0048138
08	MANUFACTURING FOOD	0.000000	0.000000	0.000036	0.000000	0.000176	0.0106684
09	TEXTILE & APPAREL ACCESSORIES	0.001192	0.000338	0.000861	0.000901	0.002429	0.0078416
10	WOOD & WOOD PRODUCTS	0.060429	0.000401	0.000000	0.000962	0.003760	0.0013930
11	PULP PAPER & ALLIED PRODUCTS	0.001757	0.000108	0.001705	0.004839	0.014213	0.0196148
12	RUBBER & RUBBER PRODUCTS	0.000638	0.000000	0.000027	0.016122	0.000183	0.0025673
13	PETROCHEMICAL RAW MATERIALS	0.000000	0.000000	0.000000	0.000000	0.000000	0.0041145
14	OTHER INDUSTRIAL CHEMICALS	0.000087	0.000002	0.002854	0.000350	0.000000	0.0013094
15	CHEMICAL FERTILIZER	0.000000	0.000000	0.000000	0.000000	0.000000	0.0000010
16	PLASTICS & PLASTIC PRODUCTS	0.021879	0.000016	0.001911	0.000000	0.012052	0.0143534
17	MISC CHEMCIAL MANUUFACTURES	0.010521	0.000027	0.002827	0.001000	0.000071	0.0092581
18	PETROLEUM REFINING PRODUCTS	0.008051	0.352958	0.451288	0.161197	0.015567	0.0040864
19	CEMENT & CEMENT PRODUCTS	0.128983	0.000000	0.000000	0.000034	0.000000	0.0023453
20	MISC NON METAL MINERAL PRODS	0.054958	0.000011	0.000009	0.000000	0.000014	0.0040240
21	STEEL & IRON	0.115933	0.000137	0.005788	0.000769	0.000000	0.0098337
22	ALUMINUM	0.001240	0.000000	0.000000	0.000000	0.000000	0.0001788
23	MISC METALS	0.000186	0.000000	0.001158	0.000001	0.000000	0.0005989
24	METALLIC PRODUCTS	0.039082	0.000284	0.000215	0.000958	0.000040	0.0026093
25	MACHINERY	0.003049	0.000117	0.012240	0.000954	0.001306	0.0099835
26	ELECTRICAL APPARATUS & EQUIP	0.034819	0.005305	0.000117	0.004902	0.000890	0.0079765
27	TRANSPORT EQUIPMENTS	0.000929	0.000922	0.008731	0.054957	0.005845	0.0037706
28	MISC MANUFACTURES	0.000851	0.001417	0.001624	0.001513	0.002580	0.0076801
29	CONSTRUCTION	0.000852	0.001138	0.002925	0.004327	0.004702	0.0227501
30	ELECTRICITY	0.003043	0.071235	0.032744	0.010001	0.010799	0.0119800
31	GAS & CITY WATER	0.000611	0.000288	0.051175	0.001313	0.003532	0.0033064
32	TRANSPORTATION & COMMUNICATIONS	0.032192	0.008521	0.003957	0.063331	0.049671	0.0191716
33	WHOLESALE & RETAIL TRADE	0.040676	0.001900	0.005563	0.004630	0.004292	0.0087514
34	MISC SERVICES	0.033486	0.041525	0.046527	0.086620	0.126729	0.0729689

the I-O model has been recognized as a useful method for analyzing and forecasting overall economic impacts.

However, some inherent assumptions for the static I-O model should be kept in mind before presenting its applications. The first is the uniqueness assumption. This assumption precludes substitution between inputs in production and requires a one-to-one correspondence between commodities and sectors. In other words, each sector produces a single and exclusive output with a single input structure. The second is the proportionality assumption. This assumption implies that the input coefficients for each sector remain relatively constant over a relatively short-time period. The last is the additivity assumption. This assumption indicates that the total effects of carrying out production in various sectors is the sum of the separate effects, i.e., no externalities. Conceptually, these assumptions also constitute the basic limitations of the static I-O model and are very important in analysis of the I-O table.

In general, applications of the I-O model include three aspects. First, it can be used as a forecasting tool to project the output of each sector in the economy on the basis of the given changes in final demand. Second, it can be used in impact analysis to measure the total impact upon income, employment, and output resulting from a given change in final demand or domestic sectoral output. Third, it can be used to estimate the overall effect of a price change in a sector.

These applications are primarily derived from the basic balance equation of I-O (i.e., equations B.1 and B.2 in previous section). Equation B.1 can be put into matrix form as:

(B.4) $X - AX - M = F$

where A is a matrix of the direct input coefficient (a_{ij}), X is a vector of domestic gross output, M is a vector of total imports, and F is a vector of final demand. If we assume that the ratio of total imports and domestic output for each sector is fixed, then equation B.4 can be rewritten as follows:

(B.5) $X(I-A-M^d) = F$

(B.6) $X = (I-A-M^d)^{-1}F$

where M^d is a diagonal matrix representing the ratio of the import and domestic output for each sector, and I is the identity matrix. Therefore, by assuming the input structure (coefficients) remains constant, we can project the output levels of each sector given the predicted final demand for each sector from Equation B.6.

However, the assumption of fixed input coefficients may not be true in the long-term. For such projection, it is necessary to apply a dynamic I-O model rather than a statis I-O model, in which the input coefficient is modified over time (see, e.g., Miernyk et al., 1970 and Rose, 1984).

As mentioned in Chapter V, the elements of the inverse matrix ($(I-A-M^d)^{-1}$) represent the total interdependence coefficients, which indicate the total direct and indirect requirements by sectors per unit of output to final demand. Thus, from the inverse matrix, we can derive the total impacts of any change in final demand, such as increasing investment or export activity in a sector, on income and employment. In practice, they are estimated as:

(B.7) Total income effect = $(I-A-M^d)^{-1} \Delta F\ H$

(B.8) Total employment effect = $(I-A-M^d)^{-1} \Delta F\ E$

where H is the vector of direct employment compensation coefficients, defined as total employment compensation per unit of output per sector, and E is a vector of direct employment coefficients, defined as the number of employees per unit of output per sector.

For analyzing the impact of change in terms of domestic gross output such as plant shutdowns, we may use the modified inverse matrix rather than the original inverse matrix. The modified inverse matrix is calculated by dividing each element in the column of the original inverse matrix by the ondiagonal element of the column in question. Then the total impacts of change in domestic output on income, employment are estimated as:

(B.9) Total income effect = $\bar{B}\ \Delta X\ H$

(B.10) Total employment effect = $\bar{B}\ \Delta X\ E$

where $\bar{B}$ is the modified inverse matrix.

Price impacts are basically derived from Equation B.11 below. This equation provides relationships between value-added and the price. If we defined the value-added (i.e. employment compensation, taxes, profits, and capital depreciation) per unit output in the jth sector v_j as the unit price of sector j P_j received less the total cost of all purchased inputs for one unit output in sector j, then equation B.2 may be modified as follows:

(B.11) $v_j = P_j - \sum_i a_{ij} P_i$

or in matrix form:

(B.12) $$V = (I-A')P$$

where A' is the transpose of the matrix A and P is the vector of sectoral price level. Therefore, price changes stemming from changes in sectoral costs, such as increasing employment compensation or taxes, can be determined by:

(B.13) $$\Delta P = (I-A')^{-1} \Delta V$$

where ΔP and ΔV are the vectors of the percentage changes in price levels and value-added.

APPENDIX C

DATA SOURCES AND LISTING

This appendix contains four tables. The first table lists variable names and its brief description and the data source for each variable. The rest of the tables list the data.

Table C.1

DATA SOURCES

Variable Name	Description	Data Source
X_A	Total domestic aluminum consumption (ton)	Metallic Materials in Taiwan (1980), Mineral Year Book (1981)
X_C	Total domestic copper consumption (ton)	Metallic Materials in Taiwan (1980)
GDP	Gross domestic product (current NT million)	Industry of Free China
WPI	Whole sale price index	Industry of Free China
FER	Foreign exchange rate	Industry of Free China
P_C	World copper price (current US $)	World Bank (1982)
P_A	U.S. producer's price of aluminum (current US $)	World Bank (1982)
m_i	Import-output coefficient	The 1979 Taiwan Input-Output Table
l_i^s	Skilled labor - output coefficient (man/NT million)	Estimated from the research report in the CEPD (Lee, 1980)
l_i^{ns}	Non-skilled labor - output coefficient (man/NT million)	Estimated from the research report in the CEPD (Lee, 1980)
k_i	Capital - output coefficient	Estimated from the research report in the CEPD (Lee, 1980)

Table C.1 (Continued)

Variable Name	Description	Data Source
e_i	Electricity - output coefficient (kiloliter oil equivalent/NT million)	Estimated from the research report in the CEPD (Lee, 1980)
g_i	Gasoline - output coefficient (kiloliter oil equivalent/NT million)	Estimated from the research report in the CEPD (Lee, 1980)
f_i	Fuel oil - output coefficient (kiloliter oil equivalent/NT million)	Estimated from the research report in the CEPD (Lee, 1980)
v_i	Value-added - output coefficient	The 1979 Taiwan Input-Output Table
FI	Total fixed investment in 1980-1984 (1979 constant NT million)	The CEPD's Ten-Year Economic Development Plan for Taiwan, R.O.C. (1980)
L^s	Total supply of skilled labor in 1984 (man)	Estimated from the research report in the CEPD (Lee, 1980)
L^{ns}	Total supply of non-skilled labor in 1984 (man)	Estimated from the research report in the CEPD (Lee, 1980)
EL	Total supply of electricity in 1984 (kiloliter oil equivalent)	Estimated from the research report in the CEPD (Lee, 1980)
GS	Total supply of gasoline in 1984 (kiloliter oil equivalent)	Estimated from the research report in the CEPD (Lee, 1980)

Table C.1 (Continued)

Variable Name	Description	Data Source
FL	Total supply of fuel oil in 1984 (kiloliter oil equivalent)	Estimated from the research report in the CEPD (Lee, 1980)
ACD	Annual capital depriciation (1979 constant NT million)	Estimated from the 1979 Taiwan Input-Output Table

Table C.2

DATA LISTING

Year	X_A	X_C	GDP	WPI	FER	P_A	P_C
1971	29,800	33,146	262,247	0.469	40.10	639	1,080
1972	34,328	42,753	314,301	0.490	40.10	582	1,071
1973	51,900	57,577	407,535	0.602	38.10	551	1,786
1974	47,300	52,916	545,024	0.846	38.05	751	2,059
1975	50,100	59,628	584,494	0.804	38.05	877	1,237
1976	64,300	77,017	701,117	0.826	38.05	978	1,401
1977	79,200	87,219	816,943	0.849	38.05	1,132	1,310
1978	108,200	96,691	970,269	0.879	36.05	1,170	1,367
1979	115,897	109,390	1,164,073	1.000	36.08	1,310	1,985
1980	133,668	118,466	1,442,870	1.216	36.06	1,531	2,182

TABLE C.3

DATA LISTING

CODE		m_i	l_i^s	l_i^{ns}	k_i	e_i	g_i	f_i	v_i
01	AGRICULTURE	0.5005	0.03604	13.3162	3.08830	1.0477	0.6949	0.333	0.677281
02	LIVESTOCK	0.0419	0.17568	1.8974	0.31482	1.3954	0.1059	0.212	C.C77214
03	FORESTRY	4.0874	0.37831	0.5761	1.90423	0.1160	0.8680	0.119	C.888636
04	FISHERIES	0.0725	1.56132	2.3406	2.42752	0.1897	0.0000	11.495	C.605606
05	COAL & COAL PRODUCTS	0.6842	3.29616	3.4516	2.76338	8.0779	C.6518	0.905	C.479112
06	CRUDE OIL & NATURAL GAS	13.5819	0.56407	0.1655	2.33539	0.3508	1.3347	8.768	C.854348
07	OTHER MINERALS	0.5377	2.23089	1.4631	0.46470	2.0031	1.9698	2.283	0.596032
08	MANUFACTURING FOOD	0.0826	0.18636	1.0112	0.82513	2.3334	0.1786	2.357	0.253774
09	TEXTILE & APPAREL ACCESSORIES	0.0546	0.12239	1.9912	1.14081	3.3936	0.0652	2.524	C.283816
10	WOOD & WOOD PRODUCTS	0.0260	0.26585	1.8042	0.91864	3.5461	0.1379	2.695	0.331960
11	PULP PAPER & ALLIED PRODUCTS	0.1284	0.33465	1.3994	1.21992	7.3576	0.1623	6.907	0.350089
12	RUBBER & RUBBER PRODUCTS	0.1504	0.62325	1.9052	0.97916	5.9783	C.3168	2.329	0.384560
13	PETROCHEMICAL RAW MATERIALS	0.5023	0.16583	0.1852	1.69218	15.0468	0.5035	3.239	C.241613
14	OTHER INDUSTRIAL CHEMICALS	0.5790	0.18149	0.2027	1.85200	16.4678	0.5511	3.545	C.309854
15	CHEMICAL FERTILIZER	0.0812	0.17030	0.2024	0.90339	9.5476	0.0942	9.367	0.208217
16	PLASTICS & PLASTIC PRODUCTS	0.0696	0.31081	1.4564	2.20914	3.6339	0.2921	1.611	0.286063
17	MISC CHEMCIAL MANUUFACTURES	0.5854	0.48862	1.7477	1.14547	2.5337	C.3869	1.957	C.285804
18	PETROLEUM REFINING PRODUCTS	0.1290	0.01540	0.0074	0.36294	1.1175	3.1055	8.616	C.161465
19	CEMENT & CEMENT PRODUCTS	0.0030	0.13971	0.2795	1.91106	18.9259	0.2610	26.363	C.485190
20	MISC NON METAL MINERAL PRODS	0.1360	0.45768	2.9770	1.43366	6.8936	C.3416	15.817	C.443064
21	STEEL & IRON	0.4573	0.44917	0.4379	5.68763	8.0478	0.0641	3.260	C.225929
22	ALUMINUM	0.5384	0.54608	0.3243	1.89274	24.6533	0.1193	6.169	0.160387
23	MISC METALS	1.5490	0.35968	0.5144	0.31109	5.3730	0.1286	2.226	0.247975
24	METALLIC PRODUCTS	0.1632	0.41367	0.6059	0.46585	6.1014	0.1554	2.836	0.357118
25	MACHINERY	0.9501	0.64362	0.4559	0.58427	1.9770	0.1113	0.753	C.360843
26	ELECTRICAL APPARATUS & EQUIP	0.2961	0.23522	0.4284	0.38197	2.0288	0.1350	1.125	C.292764
27	TRANSPORT EQUIPMENTS	0.3113	1.05456	0.7204	1.50269	3.0151	C.3607	1.518	0.331903
28	MISC MANUFACTURES	0.3901	1.08405	6.5749	3.00303	4.0676	0.0558	0.408	C.409754
29	CONSTRUCTION	0.0002	1.09414	2.0126	0.45070	2.2953	0.4548	2.072	C.365767
30	ELECTRICITY	0.0037	0.14185	0.0603	5.32801	11.4023	5.6222	142.456	C.446322
31	GAS & CITY WATER	0.0117	0.17323	0.2049	1.37078	6.8441	3.5482	8.163	C.321722
32	TRANSPORTATION & COMMUNICATIONS	0.1688	0.73959	0.3159	3.05871	1.5610	23.5490	0.220	C.580111
33	WHOLESALE & RETAIL TRADE	0.0000	0.97004	5.2985	0.74880	2.9975	1.0073	0.000	C.740347
34	MISC SERVICES	0.1298	0.80393	0.4651	1.09609	0.4826	0.2336	0.221	0.723079

Table C.4

DATA LISTING

Category	Total Supply
FI	2,161,300
L^s	1,840,746
L^{ns}	6,403,513
EL	15,201,228
GS	5,250,673
FL	18,263,215
ACD	109,129

THE POTENTIAL IMPACT AND OPTIMAL ADJUSTMENT ASSOCIATED WITH AN ALUMINUM SUPPLY RESTRICTION: A CASE STUDY OF TAIWAN

by

Chia-Yon Chen

ABSTRACT

There is a growing concern over the impact of critical mineral supply restrictions on the economies of mineral importing nations such as Taiwan. The objective of this dissertation is to build a framework that can be used to analyze the impact of a supply restriction and that can be used to formulate an optimal adjustment pattern for a national economy.

The study contains several important advances over previous studies of the impact of a commodity supply restriction. First, the model presented here generalizes I-O analysis via a linear programming (LP) framework in order to simultanously handle the production function and the allocation function. Second, substitution among related commodities, as estimated by a translog production function, is incorporated into the activity analysis in order to include a part of the price induced effect. Third, the model is able to calculate the optimal adjustment pattern subject to practical constraints. This is of great importance to policy makers, because the assessment of the sensitivity of each sector to a supply restriction and the formulation of practical adjustments are among their major concerns.

The study yields several important conclusions:

First, the models developed and tested in Chapter III, IV, VI, VII and VIII each have their strengths and weaknesses. However, as a group they have proven reasonably good in their ability to show the impact of a supply restriction and to present an optimal response.

Second, even if the elasticity of substitution between aluminum and copper is very low, an impact analysis that omits the substitution effect would still significantly overestimate the impact of a supply restriction.

Third, both consumers' surplus analysis and the "supply-driven" I-O model may overestimate the impact in the case of a mild supply restriction, and underestimate the impact in the case of a severe supply restriction.

Fourth, the LP model presented in Chapter VII is better able to provide the accurate results in analyzing the impact of a supply restriction since it is a general equilibrium solution. Its results also reflect the conceptual discontinuity of supply restriction impacts.

Fifth, the allocation function derived from the optimal solution is a very important innovation, since it allows policy-makers to readily construct an optimal adjustment strategy.

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