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**THE ROLE OF  
MAJOR NONFUEL MINERALS  
IN THE ASIAN PACIFIC  
RIM ECONOMIES**

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**UNITED STATES DEPARTMENT OF THE INTERIOR • BUREAU OF MINES**



# **The Role of Major Nonfuel Minerals in the Asian Pacific Rim Economies**

**By Julius C. Chang**

**UNITED STATES DEPARTMENT OF THE INTERIOR  
Bruce Babbitt, Secretary  
BUREAU OF MINES**

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# THE ROLE OF MAJOR NONFUEL MINERALS IN THE ASIAN PACIFIC RIM ECONOMIES

By Julius C. Chang<sup>1</sup>

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## ABSTRACT

This report analyzes the demand for primary aluminum, refined copper, lead, and zinc in nine Asian Pacific Rim countries for the past 20 to 30 years. The countries covered are Japan, the Republic of Korea, Taiwan, Hong Kong, and five member countries of the Association of Southeast Asian Nations—Singapore, Malaysia, Thailand, Indonesia, and the Philippines.

The first half of the report describes the consumption patterns of the four metals in each of these countries in

relation to the economic growth and trade patterns in the past 20 to 30 years. The last half develops a two-tier modeling approach to explain the factors affecting minerals demand and to estimate the metal demand models for each country. Of the many factors affecting minerals demand, it is found that intrasectoral structural changes (i.e., changes in product composition within a sector such as manufacturing) are the ones causing mineral intensity of use to rise and fall in the course of economic development, a phenomenon suggested by the mineral intensity of use hypothesis.

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## SUMMARY

The Asian Pacific Rim countries included in this study are Japan, the Republic of Korea, Taiwan, Hong Kong, and five member countries of the Association of Southeast Asian Nations (ASEAN)—Singapore, Malaysia, Thailand, Indonesia, and the Philippines. During the past 20 to 30 years, these nine countries in general have demonstrated a high rate of economic growth, attracting worldwide attention. Their mineral requirements consequently have increased rapidly, making them an important consuming block with an increasing clout to influence the world's mineral markets. The Asian Pacific Rim countries separately represent three levels of economic development. According to the World Bank classification, Japan is the only industrialized country in the group. On the other hand, the ASEAN countries minus Singapore are developing countries and

will be referred to as the ASEAN Four henceforth. In between are the newly industrialized countries (NIC's) of the Republic of Korea, Taiwan, Hong Kong, and Singapore. These countries as a group provide a convenient framework within which to analyze how minerals demand may change as countries go through different stages of economic development. Understanding the dynamics of such a relationship is crucial for forecasting future minerals demand and assessing future industry developments. The minerals covered in the study are primary aluminum, refined copper, lead, and zinc.

In this study, the consumption patterns of the four metals in each of the nine countries are analyzed in relation to the respective economic growth and trade patterns during the past 20 to 30 years. Then the theoretical models are developed to analyze the factors affecting minerals demand and to estimate statistically the relationship between these fac-

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tors and metals demand, using empirical data. The summary of findings follows.

### THE DESCRIPTIVE ANALYSIS

The analysis indicates that Japan's consumption of the four nonfuel minerals increased faster than the real gross domestic product (GDP) during the 1960's, when the latter was growing at a double-digit pace. Its mineral intensity of use, which is the ratio of the amount of the mineral consumed to the constant dollar GDP, thus rose sharply during this period, confounding many analysts who expected Japan's mineral intensity of use to follow the downward trends that had been observed in other industrialized countries. Since the early 1970's, however, as the economic growth slowed down from the torrid pace of the 1960's, the rates of increase in minerals consumption also dropped gradually. The declining trends of mineral intensity of use developed since then have brought Japan back in line with the experience of other advanced countries—a phenomenon known as the “decoupling” of minerals from the economy.

Nonetheless, Japan has become one of the world's major minerals consumers, trailing only the United States. In 1988, Japan consumed 2.1 million metric tons of primary aluminum, 1.3 million metric tons of refined copper, and 0.77 million metric tons of refined zinc, according to the World Bureau of Metal Statistics. These figures represented about 15% of the respective Western World's total consumption. The same source indicates Japan consumed 0.4 million metric tons of lead (including secondary lead), accounting for 9.4% of the Western total. To compare with the United States, Japan consumed about 46% of the primary aluminum, 60% of the refined copper, 70% of the refined zinc, and 33% of the lead that the United States consumed in 1988.

The economies of the Republic of Korea, Taiwan, Singapore, and Hong Kong also experienced a rapid growth in the 1970's and 1980's. Minerals consumption, which was negligible during the 1960's, has soared since then. However, the increases in minerals consumption in Singapore and Hong Kong have been relatively moderate, as their economies are more heavily weighted with trade and financial services. Minerals consumption has grown most spectacularly in the Republic of Korea and Taiwan. In the Republic of Korea, consumption of the four minerals increased at a compound annual rate of around 17% to 18%, about twice the growth rates of real GDP in 1970-88. In Taiwan, consumption of copper and lead also grew at a comparable rate (19% and 15%, respectively), but that of aluminum and zinc grew at about the same rate as the real GDP (9.4%). Consequently, the Republic of Korea's min-

eral intensity of use has been on the rise for all four minerals. Similarly, Taiwan's copper and lead use intensities also show an upward trend, but its aluminum and zinc use intensities appear to have reached a plateau since the late 1970's. In 1988, the Republic of Korea consumed about 270,000 metric tons of primary aluminum and refined copper, respectively; 173,000 metric tons of zinc; and 146,000 metric tons of lead. The corresponding consumption figures for Taiwan were 176,000 metric tons of aluminum, 225,000 metric tons of copper, and 75,000 metric tons of zinc and lead, respectively. In 1988, these two countries consumed about one-fifth of the aluminum; one-third of the copper and zinc, respectively; and one-half of the lead that Japan consumed in the same year.

Considered the next tier of the NIC's, the ASEAN Four as a group have maintained a strong economic growth during the last two decades that was about 2% to 3% lower than that of the Asian NIC's. The performance of the individual countries varied, however, with Thailand in the lead, followed by Malaysia, Indonesia, and the Philippines, in that order. Minerals consumption in these countries generally followed economic growth patterns. Except for the Philippines, minerals consumption in these countries increased in most cases at a double-digit rate in 1971-88. However, the consumption levels of each country are still relatively low. In 1988, these countries as a group consumed 172,000 metric tons of primary aluminum, 100,000 metric tons of refined copper, 166,000 metric tons of zinc, and 55,000 metric tons of lead. These figures represent about two-fifths of the aluminum, one-fifth of the copper, two-thirds of the zinc, one-quarter of the lead consumed by Taiwan and the Republic of Korea in the same year.

In terms of mineral intensity of use, the ASEAN Four show a varying degree of upward trend for primary aluminum, refined copper, and lead but a flat pattern for refined zinc.

### THE STATISTICAL ANALYSIS

Mineral demand is known to be affected by income and mineral intensity of use. The latter, in turn, is affected by the material composition of products and the product composition of income. The material composition of products changes as changes in technology and the relative prices of minerals cause input substitutions in the production process. The product composition of income changes as the relative importance of sectors in the economy as well as subsectors within a sector changes in the course of economic development. The former is known as the intersectoral change and the latter as intrasectoral change in the structure of the economy. A notable example of intersectoral change is the rise of the manufacturing sector at the expense of others, and an example of intrasectoral

change is the shift in the relative importance of component output such as from light manufactured goods to heavy industry products within the manufacturing sector.

Many efforts to develop mineral demand models have encountered difficulties because technology and economic structure are not quantitatively observable. To circumvent this problem, a two-tier modeling approach is adopted in this study to construct a proxy for the unobservable variables.

In the first-tier modeling, a measure of technological and price changes and intrasectoral change in economic structure is estimated, respectively, in a cross-country regression for the initial year of the sample period. A time series for these estimates is then developed by repeating the same procedure for the successive years.

The results indicate that the technological and price factors do not seem to have a net effect on the copper demand. These factors, however, are found to have affected the use intensity of the other three metals in a negative way. A large impact on the aluminum demand is detected for 1983-85, reducing the average aluminum use intensity among the countries by about 1.3 metric tons (mt) per million dollars of GDP (1980 prices) annually in 1985-88. The impact for the zinc use intensity appears relatively moderate. It has zigzagged between 0 and -0.25 mt per million dollars of GDP (1980 prices) since 1974. The impact of technological and price factors on lead demand is more pronounced. Since 1976, it has caused the average lead use intensity to decline, with the downward trend accelerating in 1986-88. In 1978, it caused the average lead use intensity to decrease by 0.15 mt per million dollars of GDP (1980 prices). This figure increased to 0.79 mt in 1988, indicating a somewhat accelerated trend of other materials being substituted for lead.

In the second-tier modeling, the estimated measures of technological and price changes and intrasectoral change in the economic structure are used along with other legitimate

explanatory variables to estimate the mineral demand models for each country. The results indicate an excellent data fitting in all cases.

Of the explanatory variables related to minerals demand, real GDP, representing income as well as intersectoral changes in the economy, is statistically significant in all estimated demand models. The two proxy variables for technological and price changes and intrasectoral change also prove to be statistically significant in the majority of the estimated models.

The estimated demand models indicate that the demands for all four minerals increase with income and intersectoral change in the economy, as reflected in the real GDP. The demands for aluminum, lead, and zinc, however, are dampened in a varying degree by the net substitution effects stemming largely from technological change. The intrasectoral change in the economy also affects minerals demand, with the impact largely depending on the stage of economic development. In general, the positive impacts of intrasectoral change in the economy on minerals demand are declining in Japan but increasing in the developing countries. These impacts tend to be reinforced by the growth patterns of income and manufacturing sector, which are rising at a faster rate in the developing countries than in Japan. As a result, mineral intensity of use tends to increase in the developing countries and to decline in Japan.

This analysis appears to be in line with the mineral intensity of use hypothesis, which, based on the experiences of the industrialized countries, postulates that mineral intensity of use tends to rise in the early period of economic development and decline later in a more advanced stage. The implication of the hypothesis is that economic development alone can largely explain the behavior of mineral intensity of use. However, such a simplistic approach is inadequate and cannot be justified, given the multiplicity of variables known to be affecting mineral intensity of use.

## INTRODUCTION

### BACKGROUND AND OVERVIEW

Minerals are internationally traded commodities. Where and how much they are consumed abroad could have as much impact on the United States as where and how much they are produced in the rest of the world. Understanding of mineral consumption trends worldwide and the changes in the underlying factors thus is important for addressing one of the Bureau's goals of ensuring adequate supplies of minerals to meet the economic and defense needs of the Nation.

For this reason, from time to time, the Bureau has conducted mineral demand studies along with its ongoing supply analysis programs. This study focuses on the demand for four minerals in nine Asian Pacific Rim countries. The countries are selected because of their rapid economic growth and the concomitant increases in minerals consumption.

The Asian Pacific Rim countries, for the purposes of this study, include Japan, the Republic of Korea, Taiwan, Hong Kong, Singapore, Indonesia, the Philippines, Malaysia, and Thailand. In geography, these countries roughly form an

arc alongside the Asian continent, stretching from the Hokkaido island of Japan southward to the Malaysian peninsula and turning southeastward to the eastern end of the archipelago of Indonesia in the South Pacific sea. Singapore, Indonesia, the Philippines, Malaysia, and Thailand are members of the Association of Southeast Asian Nations (ASEAN). (The other member is Brunei, which is excluded from this study for lack of data.) The latter four countries as a group will be referred to as the ASEAN Four henceforth.

The Asian Pacific Rim countries are diverse; they differ widely in size, population, language, culture, and ethnic background. Whereas Japan and Indonesia are large countries with a population in excess of 120 million and 190 million, respectively, Singapore and Hong Kong, on the other hand, are tiny city-states, each with a population of only 2.7 million and 5.7 million respectively. (Strictly speaking, Hong Kong is not an independent state but will be treated as such for expository purpose.) Except Taiwan, Hong Kong, and Singapore, where the majority of the populace share the same ancestry in China, the peoples in these countries all claim unique nationality, speak different languages, and feature diverse cultures and religions.

The countries in the north are poor in natural resources. Japan almost has exhausted its meager mineral reserves after decades of economic development. The Republic of Korea and Taiwan are likewise poor in natural resources. For the city-states of Singapore and Hong Kong, which thrive as entrepôts for world trade, the harbor is the only natural resource. The ASEAN Four in the south, on the other hand, are resource rich. Indonesia is noted for its petroleum and liquefied natural gas as well as tin, copper, gold, and nickel. Malaysia is the world's leading producer of tin and liquefied natural gas. Thailand and the Philippines have tin, gold, copper, chromium, nickel, and cobalt, to mention a few.

Immediately after World War II, the economies of the Pacific Rim countries, especially those in the north, faced a bleak, uncertain future. Except for Thailand, the ASEAN countries were not even independent states. There was a plentiful labor supply, but severe capital shortages and insufficient foreign exchange hampered economic progress in the region. Unemployment was high and inflation rampant. U.S. economic aids were crucial in sustaining the economies of Japan, the Republic of Korea, and Taiwan.

However, since 1960, the region has flourished with an almost uninterrupted economic growth, attracting worldwide attention. The most notable country is Japan, whose economic success in the 1960's had put it back into the group of the world's most industrialized countries. In pursuit of Japan are the "Four Mini-Dragons," the Republic of Korea, Taiwan, Hong Kong, and Singapore, more formally known as the newly industrialized countries (NIC's).

The resource-rich ASEAN Four make up the next tier of the NIC's. With the natural inclination to develop the primary goods sectors first, they have not done as well as the "Four Mini-Dragons." Nevertheless, their economies have grown consistently at a high rate, outperforming many other countries in the world. Furthermore, since the mid-1980's, the ASEAN Four have become the beneficiaries of direct foreign investment, notably from Japan and the NIC's. Direct foreign investments are doing to the ASEAN Four what they did to the NIC's more than a decade ago—setting in motion the process of industrialization and the expansion of an export-driven economy. Consequently, these countries are being transformed from a resource-based economy to one diversified with manufacturing capabilities, although the progress varies by country. With their economies expected to continue to grow at a faster pace in the 1990's, they are considered to be in a position to follow the footsteps of the NIC's.

To put it in perspective, the real gross domestic product (GDP) of Japan and the ASEAN Four increased more than fivefold, and that of the NIC's increased more than 11 times in 1969-89. (These compared to the GDP growth of 2.4 times for the United States and 3.1 times for the world's market economies as a whole.) Meanwhile, the real GDP share of all these countries in the world total (not including the Eastern Bloc) doubled from 7.2% to 15%, and the trade share (exports plus imports) rose from 7.4% to more than 19% during the same period. Table 1 below provides an overview of how the economies in the regions had grown in the past 30 years.

**Table 1.—Real GDP growth of the Asian Pacific Rim countries**  
(Annual compound rate in percentage)

| Countries         | Year    |         |         |         |
|-------------------|---------|---------|---------|---------|
|                   | 1960-69 | 1970-79 | 1980-85 | 1985-88 |
| Japan             | 10.4    | 4.7     | 3.9     | 4.4     |
| Republic of Korea | 7.9     | 9.8     | 8.4     | 10.5    |
| Taiwan            | 9.5     | 10.0    | 6.7     | 9.7     |
| Hong Kong         | 9.3     | 9.2     | 5.6     | 8.8     |
| Singapore         | 8.7     | 8.9     | 6.2     | 7.9     |
| Thailand          | 8.0     | 7.0     | 5.6     | 9.9     |
| Malaysia          | 6.5     | 7.9     | 5.1     | 6.0     |
| Philippines       | 5.2     | 6.2     | -0.6    | 4.5     |
| Indonesia         | 4.0     | 7.7     | 5.0     | 6.0     |

Source: The World Bank.

These fast economic expansions would not have been possible without consumption of large quantities of raw materials and minerals. In 1988, Japan consumed 2.1 million metric tons of primary aluminum, 1.3 million tons of refined copper, and 0.77 million tons of zinc, according to

the World Bureau of Metal Statistics. These figures represented about 15% of the respective Western World's total consumption. Japan consumed about 46% of the primary aluminum, 60% of the refined copper, 70% of the refined zinc, and 33% of the lead that the United States consumed in 1988.

So far, Japan leads the region in minerals consumption. But since the early 1970's, as its economic growth has slowed down from the double-digit rates of the 1960's, the rates of increase in minerals requirements have also slowed. On the other hand, as the other countries catch up in the race toward industrialization, demands for minerals by these countries have been growing at an increasing rate. In 1988, the NIC's and the ASEAN Four together consumed 31% of the primary aluminum, 44% of the refined copper, 59% of the refined zinc, and 76% of the lead consumed by Japan; 10 years earlier, these ratios were only 18%, 10%, 35%, and 23%, respectively. Further growth of mineral demands in the 1990's thus will most likely come from these less advanced countries. In 1989, the Asian Pacific Rim countries produced 15% of the world's GDP (not counting the Eastern Bloc), while accounting for 19% of the world's primary aluminum consumption and 23% of the world's refined copper and zinc consumption. According to an estimate by the Japanese Economic Research Center, economic growth will be 1.5 times faster in Asia than the world average in the future decades, and by 2050, Asia will account for about one-half of the world's total GDP. The potential of the Asian Pacific Rim countries—or for that matter, of the whole Asian region—as increasingly important minerals consumers is immense, and it could have far-reaching implications for the world's mineral markets.

## STUDY OBJECTIVE AND PLAN

The purpose of the study is to analyze the demand for selected major nonferrous metals in the Asian Pacific Rim countries in relation to economic growth, exports, and shifts

in the product composition. At this time, the Asian Pacific Rim countries represent three different stages of economic development—the industrialized, the newly industrialized, and the developing. Each stage of development reflects a varying degree of labor proficiency, manufacturing skill, and technological sophistication as embodied in the quality and product mix of their output. These countries thus provide a convenient framework within which to analyze how mineral consumption patterns may change as countries climb up the economic ladder and their product composition is upgraded in the process.

The analysis will shed light on such questions as “Do the rates of minerals consumption vary by the stage of economic development?,” “At what stage do the rates of minerals consumption increase or decrease?,” and “Will a highly industrialized world economy entail more or less use of minerals?” These questions could have profound implications for the future of the world's minerals industries, as the answers portend the extent to which the products and services of the industries will be needed. By quantitatively accounting for the relationship between minerals demand and economic growth, the analysis also will contribute to improving the methodology for forecasting minerals demand. Because of the time constraints, the minerals selected for the study are limited to four nonferrous metals: primary aluminum, refined copper, refined zinc, and lead.

The next section of this report provides a country-by-country review of economic growth, trade developments, and the patterns of minerals consumption based on the observed data. In the third section, after a literature review of the methodologies and models used in the past, the metals demand models, which incorporate the existing theoretical concerns and the special features observed from the review in the previous section, are developed. These theoretical models are confronted with empirical data in a series of statistical estimations and hypothesis testings in the fourth section. Some implications of the statistical results are discussed further in the fifth section. The last section summarizes the study findings.

## PATTERNS OF ECONOMIC GROWTH, TRADE, AND MINERALS DEMAND

This section reviews the consumption of the four metals by the Asian Pacific Rim countries, in light of their economic developments over the past two to three decades. Japan is discussed first, followed by the NIC's and the ASEAN Four. This discussion roughly represents three different levels of economic development: the industrialized, the newly industrialized, and the developing. In each case, the overall economic growth and trade developments are discussed first, as exports have played a key role in their

growth. This is then followed by the discussion of the metals consumption in terms of absolute amounts as well as a relative measure, known as mineral intensity of use calculated as the ratios of physical units of mineral used to real GDP. The main purposes here are to develop a sense of how minerals consumption patterns can be associated with different stages of economic development from a historical perspective and to prepare empirical data for use in the next section where a more rigorous analysis of the relation-

ship between minerals consumption and economic growth is performed. The GDP data used are provided by the Economic and Social Statistics Division of the World Bank. The consumption data for primary aluminum, refined copper, zinc, and lead are taken from various issues of Metal Statistics.

## JAPAN

### Patterns of Economic Growth and Trade

Japan was the only industrialized country in the Far East before World War II, but its economy in the aftermath of the war was trapped in a vicious circle of stagnation. The shortage of foreign exchange prevented raw material imports, and the lack of raw materials stunted industrial production, which in turn cramped the ability to earn foreign exchange. This grim plight, however, changed suddenly with the outbreak of the Korean War on June 25, 1950. As war-related purchases by the Allied forces, known as "special procurements," poured in, the fledgling Japanese economy was transformed instantly into the humming factory of the Allied forces. Industrial production spurted 50% within a year, and the surging exports enabled Japan to earn enough foreign exchange to post a positive balance of payments in 1951 for the first time in its postwar history (Kawahito, 1972). Although the stimulus did not last long (the war ended in 1953), it provided Japan with an opportunity to break the vicious circle of impoverishment and set out on the path to economic preeminence.

During the 1960's, the real GDP grew at an annual compound rate of 10.4% and almost tripled in the decade. The annual growth rate slowed to 4.7% in the 1970's because of the oil shocks of 1973-74 and 1979-80 and moderated further to 4.1% in the 1980's. The real GDP growth rates nevertheless topped those of other industrialized nations. The growth of Japanese real GDP is graphed in figure 1.

From the mid-1950's to the mid-1960's, import substitution and domestic investment were the main sources of economic strength. Main export items were limited to low-skill, labor-intensive, low-value added manufacturing products such as footwear, cloth, textiles, plastic products, radios, and transistors. Because of high saving rates, investment averaged 35% of real GDP each year in the 1960's, resulting in a rapid accumulation of physical capital and upgrading of human resources, which, in turn, enhanced further the economy's capabilities to produce at home and compete abroad.

The drive to export received an added impetus in the 1970's as the domestic market became saturated in the face of high saving rates. Export share of GDP, which remained flat (about 11%) in 1965-70, rose gradually to 14% in the

late 1970's. Major export items also shifted to a mix of products that were more capital intensive, of high-skill labor, and high value added. It was during this period that Japan started to establish a foothold in the world's major automobile markets and went on to dominate the global markets for consumer electronic products.

During 1980-85, Japan's exports increased further to account for 16.1% of its GDP on the average, aided by the soaring values of the dollar. The exports, however, declined to about 13% of the GDP in 1986-87, partly in response to the lower value of the dollar engineered by the G-7 foreign ministers meeting in September 1985. The yen's appreciations, however, boosted Japan's term of trade, and her trade surplus continued to grow, reaching \$96 billion in 1987. Meanwhile, the product mix of exports reflected upgrading of product lines and high-tech products such as computers, computer chips, and semiconductors.

The sustained, rapid economic growth in Japan has wrought a change in the structure of its economy. As shown in table 2, the manufacturing and trade sectors expanded while agriculture contracted. The GDP share of the manufacturing sector increased steadily from 20.5% in 1963 to 35.4% in 1988, while that of agriculture decreased

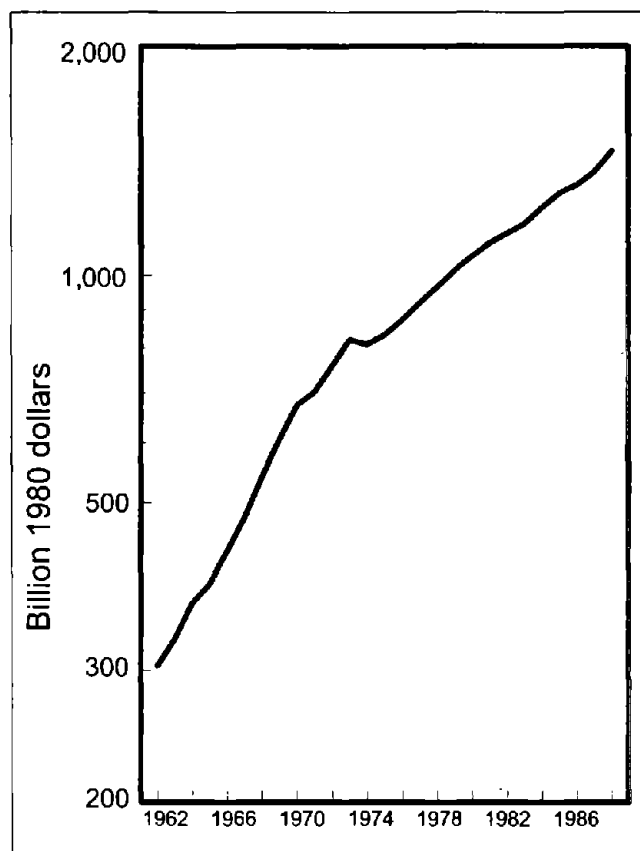


Figure 1.—Japanese GDP.

from 12.6% to a mere 2.7% during the same period. The GDP share of the trade sector also climbed from 7.3% in 1966 to 15% in 1988, reflecting the economy's increasing

**Table 2.—Japan's real GDP share by major industries  
(In percentages)**

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 12.6   | 8.3    | 5.6    | 4.2    | 3.4    | 2.7    |
| Manufacturing  | 20.5   | 24.4   | 28.0   | 27.6   | 31.7   | 35.4   |
| Construction   | 10.0   | 9.8    | 11.3   | 10.4   | 7.5    | 7.4    |
| Transportation | 6.4    | 6.9    | 6.7    | 6.2    | 6.0    | 5.6    |
| Trade          | 7.3    | 10.7   | 12.2   | 13.5   | 15.4   | 15.0   |
| Services       | 39.7   | 36.3   | 33.0   | 34.7   | 32.6   | 30.6   |
| Others         | 3.5    | 3.6    | 3.2    | 3.4    | 3.4    | 3.3    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

dependency on exports. In contrast to other advanced countries whose services sectors tend to command an increasing share of GDP, Japan has seen her services sector's share of GDP slipping from 39.7% in 1963 to 30.6% in 1988. The data underscore the importance of manufacturing industry as the core of the Japanese economy and export markets as a major source of its economic growth.

Economic expansion has also been accompanied by a continued upgrading of manufacturing capabilities from low-level, light industry, which basically uses unskilled labor and simple technology, to high-level, heavy industry, which requires skilled labor and more sophisticated technology. Such a trend, which could have ramifications on Japan's requirements for minerals, is reflected in the changes in the commodity composition of its exports over years as shown in table 3.

The table shows the value of Japan's exports by major commodity groups and the group share as a percentage of the total for 1963-88 in 5-year intervals. The commodities are grouped by the Standard Industrial Trade Classification (SITC) code, and Groups 5 to 8 are considered to be manufacturing.

Although a further breakdown of commodity groups at least to the SITC four-digit level is needed to make a more precise classification of commodities in terms of input factors content, generally speaking, Group 6—manufactured goods—contains commodities that are typically unskilled labor intensive and of low technical content. They include yarn, fabric, textile products, leather, plywood, and mineral manufactures. The same is true of Group 8—miscellaneous manufactured goods—which includes furniture, clothing, footwear, toys, scientific and optical equipment, and miscellaneous consumer products such as watches, phono-

graphs, books, and jewelry. On the other hand, Group 7—machinery and transportation equipment—is concentrated with a wide range of manufactured goods that are human resource intensive (high-skill labor) as well as technology intensive. These goods include power-generating equipment, engines, machinery, telecommunication equipment, electrical apparatus, airplanes, trains, cars and trucks, transistors, VCR's and TV's, semiconductor products, computer chips, and computers.

During the 25-year period, Japan's exports in 1988 constant prices increased fivefold. The exports are almost exclusively dominated by manufactured products, which accounted for 90.8% of the total exports in 1963, and the percentage continued to rise, reaching 98.3% in 1988. Exports of the SITC 6 category that were dominant through the 1960's had declined steadily over the years and accounted for only 13.5% of the total in 1988. On the other hand, exports of the SITC 7 category, which represented only 27% of the total exports in 1963, had increased steadily and reached 66% of the total in 1988. Exports of chemicals (SITC 5) as a percentage of the total had changed little, while those of miscellaneous manufactured goods (SITC 8) declined slightly, accounting for 13.4% of the total exports in 1988, down from 15.4% in 1963.

From 1966 to 1988, Japan's imports in the 1988 constant prices increased almost threefold. As shown in table 4, crude materials (SITC 2) and mineral fuels (SITC 3) were the most important imported items in 1963, accounting for 40.9% and 18.0%, respectively. The import share of the former then declined steadily to 14.9% in 1988, reflecting lower commodity prices and higher values of the yen rather than decreases in quantities. The import share of the latter remained around 20% over the years except in 1978 and 1983, when the share jumped to 40% and almost 50% of the total, respectively, because of higher crude oil prices. The share of manufactured goods (SITC 5-8) remained relatively stable at about one-quarter of the total imports until very recently. In 1988, the manufactured goods imports rose to 46.1% of the total, reflecting the results of yen appreciation and the gradual opening of the domestic markets under pressure by Japan's major trade partners, especially the United States and the European Community countries.

### Patterns of Minerals Consumption

Against this backdrop of the economic development, this section examines the consumption patterns of the four major nonferrous metals in Japan during the last three decades. The time-series data for the Japanese consumption of primary aluminum, copper, lead, and zinc are presented in appendix tables A-1 through A-4, and the corresponding intensity of use data in appendix tables A-5 through A-8.

Table 3.—Japan's exports by commodity groups

| SITC categories                               | 1963                 | 1968  | 1973  | 1978   | 1983   | 1988   |
|-----------------------------------------------|----------------------|-------|-------|--------|--------|--------|
|                                               | (In billions of yen) |       |       |        |        |        |
| All commodities                               | 1,959                | 4,920 | 9,929 | 20,326 | 34,573 | 33,497 |
| 0. Food and live animals                      | 101                  | 151   | 224   | 201    | 296    | 201    |
| 1. Beverages and tobacco                      | 3                    | 5     | 5     | 20     | 34     | 16     |
| 2. Crude materials                            | 59                   | 88    | 185   | 222    | 284    | 226    |
| 3. Mineral fuels and lubricants               | 6                    | 11    | 25    | 55     | 103    | 76     |
| 4. Animal and vegetable oil and fats          | 11                   | 6     | 10    | 24     | 28     | 20     |
| Manufacturing (5-8)                           | 1,779                | 4,659 | 9,478 | 19,795 | 33,798 | 32,939 |
| 5. Chemicals                                  | 113                  | 290   | 584   | 1,077  | 1,659  | 1,788  |
| 6. Manufactured goods                         | 827                  | 1,628 | 2,897 | 4,869  | 6,876  | 4,510  |
| 7. Machinery and transportation equipment     | 531                  | 1,773 | 4,943 | 11,720 | 20,224 | 22,146 |
| 8. Miscellaneous manufactured goods           | 308                  | 968   | 1,054 | 2,129  | 5,039  | 4,495  |
| 9. Miscellaneous transactions and commodities | —                    | —     | 2     | 9      | 30     | 19     |
|                                               | (In percentages)     |       |       |        |        |        |
| All commodities                               | 100.0                | 100.0 | 100.0 | 100.0  | 100.0  | 100.0  |
| 0. Food and live animals                      | 5.2                  | 3.1   | 2.3   | 1.0    | 0.8    | 0.6    |
| 1. Beverages and tobacco                      | 0.1                  | 0.1   | —     | —      | —      | —      |
| 2. Crude materials                            | 3.0                  | 1.8   | 1.9   | 1.1    | 0.8    | 0.7    |
| 3. Mineral fuels and lubricants               | 0.3                  | 0.2   | 0.2   | 0.3    | 0.3    | 0.2    |
| 4. Animal and vegetable oil and fats          | 0.6                  | 0.1   | 0.1   | 0.1    | —      | —      |
| Manufacturing (5-8)                           | 90.8                 | 94.7  | 95.5  | 97.4   | 97.8   | 98.3   |
| 5. Chemicals                                  | 5.8                  | 5.9   | 5.9   | 5.3    | 4.8    | 5.3    |
| 6. Manufactured goods                         | 42.2                 | 33.1  | 29.2  | 23.9   | 19.9   | 13.5   |
| 7. Machinery and transportation equipment     | 27.1                 | 36.0  | 49.8  | 57.5   | 58.5   | 66.1   |
| 8. Miscellaneous manufactured goods           | 15.7                 | 19.7  | 10.6  | 10.7   | 14.6   | 13.4   |
| 9. Miscellaneous transactions and commodities | —                    | —     | —     | —      | —      | —      |

— Dash denotes negligible; the column figures may not add to the total because of rounding.  
Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

The unprecedented strong economic expansion of the 1960's coincided with an even stronger growth in the demand for minerals, making Japan one of the leading minerals consuming countries in the world. Aluminum consumption increased at an annual compound rate of 23.5% in 1962-69, and consumption of copper and zinc increased around 15% each year. Lead consumption increased at a slower rate of 6.9% during the same period. As can be seen from table 5, as the pace of economic growth slowed down in the following decades, the growth in metals consumption also dropped precipitously. In the 1980's, although the

economy was still growing at a rate of 4%, copper consumption decreased slightly. It appears that the oil shock of 1973 provided a watershed, marking a reversal in the trend of minerals consumption. Nonetheless, Japan consumed 774,000 metric tons of zinc and 406,000 metric tons of lead in 1988, a more than threefold increase from consumption in 1962. Its primary aluminum and refined copper consumption reached over 2.1 million and 1.3 million metric tons in 1988, respectively, compared to a mere 184,000 and 281,000 metric tons in 1962—a growth of 1,150% and 470%, respectively.

Table 4.—Japan's imports by commodity groups

| SITC categories                               | 1963  | 1968  | 1973   | 1978   | 1983   | 1988   |
|-----------------------------------------------|-------|-------|--------|--------|--------|--------|
| (In billion yen)                              |       |       |        |        |        |        |
| All commodities                               | 2,419 | 4,660 | 10,365 | 16,607 | 29,791 | 23,751 |
| 0. Food and live animals                      | 377   | 652   | 1,563  | 2,255  | 3,339  | 3,459  |
| 1. Beverages and tobacco                      | 14    | 24    | 66     | 135    | 200    | 276    |
| 2. Crude materials                            | 989   | 1,734 | 3,281  | 3,186  | 4,261  | 3,540  |
| 3. Mineral fuels and lubricants               | 436   | 963   | 2,266  | 6,648  | 13,986 | 4,909  |
| 4. Animal and vegetable oil and fats          | 14    | 18    | 48     | 57     | 64     | 52     |
| Manufacturing (5-8)                           | 589   | 1,267 | 3,135  | 4,188  | 7,591  | 10,971 |
| 5. Chemicals                                  | 133   | 248   | 507    | 790    | 1,712  | 1,900  |
| 6. Manufactured goods                         | 122   | 465   | 1,226  | 1,385  | 2,411  | 3,503  |
| 7. Machinery and transportation equipment     | 288   | 442   | 855    | 1,206  | 2,230  | 3,112  |
| 8. Miscellaneous manufactured goods           | 46    | 112   | 547    | 807    | 1,238  | 2,456  |
| 9. Miscellaneous transactions and commodities | —     | 2     | 6      | 138    | 350    | 544    |
| (In percentages)                              |       |       |        |        |        |        |
| All commodities                               | 100.0 | 100.0 | 100.0  | 100.0  | 100.0  | 100.0  |
| 0. Food and live animals                      | 15.6  | 14.0  | 15.1   | 13.6   | 11.2   | 14.6   |
| 1. Beverages and tobacco                      | 0.6   | 0.5   | 0.6    | 0.8    | 0.7    | 1.2    |
| 2. Crude materials                            | 40.9  | 37.2  | 31.7   | 19.2   | 14.3   | 14.9   |
| 3. Mineral fuels and lubricant                | 18.0  | 20.7  | 21.8   | 40.0   | 46.9   | 20.7   |
| 4. Animal and vegetable oil and fats          | 0.6   | 0.4   | 0.5    | 0.3    | 0.2    | 0.2    |
| Manufacturing (5-8)                           | 24.3  | 27.2  | 30.2   | 25.2   | 25.5   | 46.1   |
| 5. Chemicals                                  | 5.5   | 5.3   | 4.9    | 4.8    | 5.7    | 8.0    |
| 6. Manufactured goods                         | 5.0   | 10.0  | 11.8   | 8.3    | 8.1    | 14.7   |
| 7. Machinery and transportation equipment     | 11.9  | 9.5   | 8.2    | 7.3    | 7.5    | 13.1   |
| 8. Miscellaneous manufactured goods           | 1.9   | 2.4   | 5.3    | 4.8    | 4.1    | 10.3   |
| 9. Miscellaneous transactions and commodities | —     | —     | —      | 0.8    | 1.2    | 2.3    |

— Dash denotes negligible; the column figures may not add to the total because of rounding.

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

As can be seen in table 1, which shows the real GDP growth, and figures 2 and 3, which show the metals consumption growth, the growth in metals consumption corre-

Table 5.—Japan's consumption of major nonferrous metals (Annual compound growth rate in percentages)

| Year    | Metals   |        |      |      |
|---------|----------|--------|------|------|
|         | Aluminum | Copper | Lead | Zinc |
| 1962-69 | 23.5     | 16.3   | 6.9  | 14.6 |
| 1970-79 | 8.4      | 5.1    | 7.0  | 2.6  |
| 1980-88 | 2.0      | -0.4   | 1.2  | 0.0  |

Source: Metal Statistics

sponded with the growth in real GDP until 1973. After that, the real GDP continued to grow while the growth rates of mineral consumption flattened. As a result, as exhibited in figures 4 and 5, the mineral intensity of use steadily increased until 1973 and then declined afterward.

This "decoupling" of minerals consumption from the economy is a phenomenon also observed for many industrialized countries. It is theorized that as the economies mature and diversify into areas other than mineral-intensive manufacturing activities, the amounts of minerals consumed per unit of real GDP, that is mineral intensity of use, will

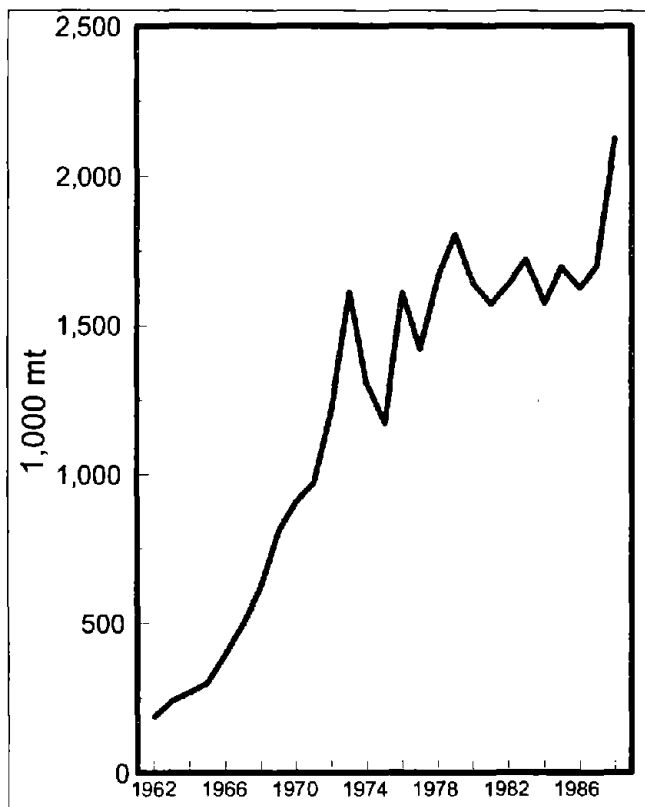


Figure 2.—Japanese consumption of primary aluminum.

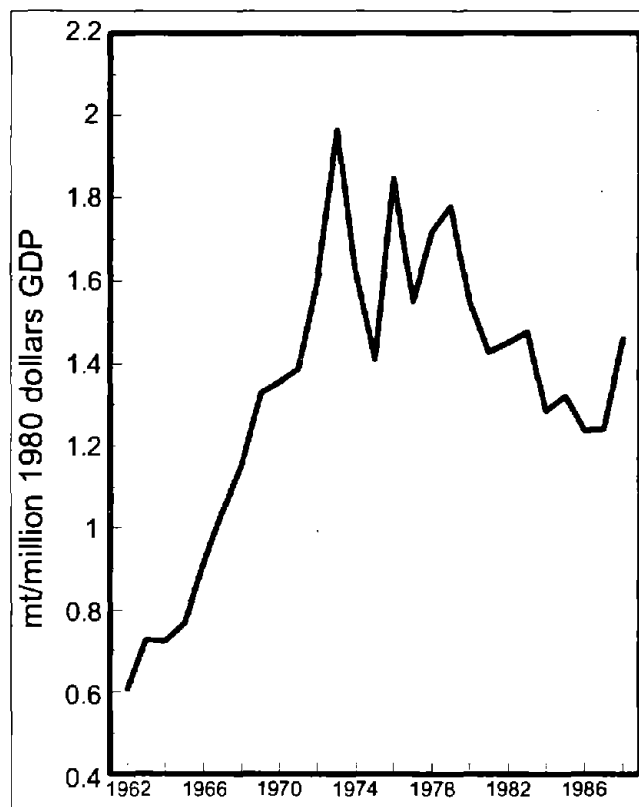


Figure 4.—Aluminum intensity of use—Japan.

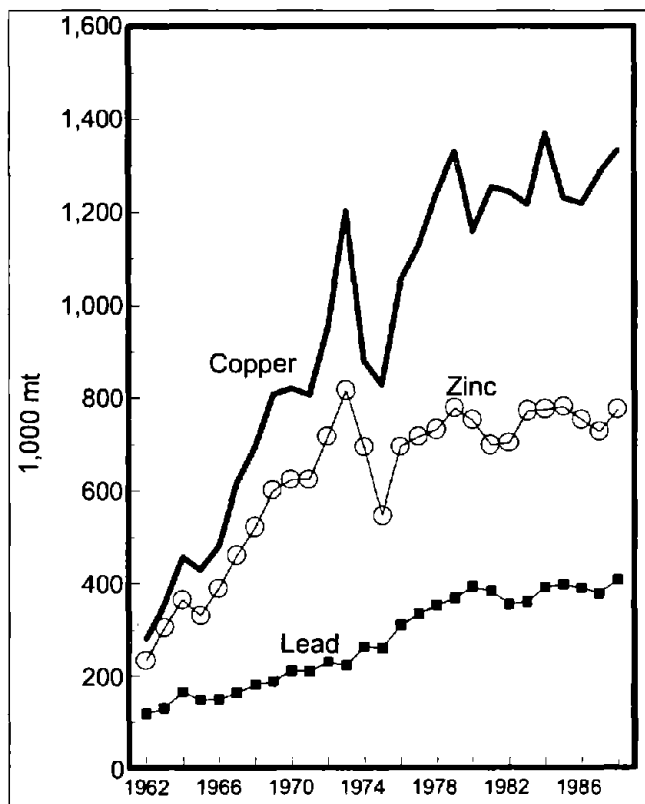


Figure 3.—Japanese consumption of copper, lead, and zinc.

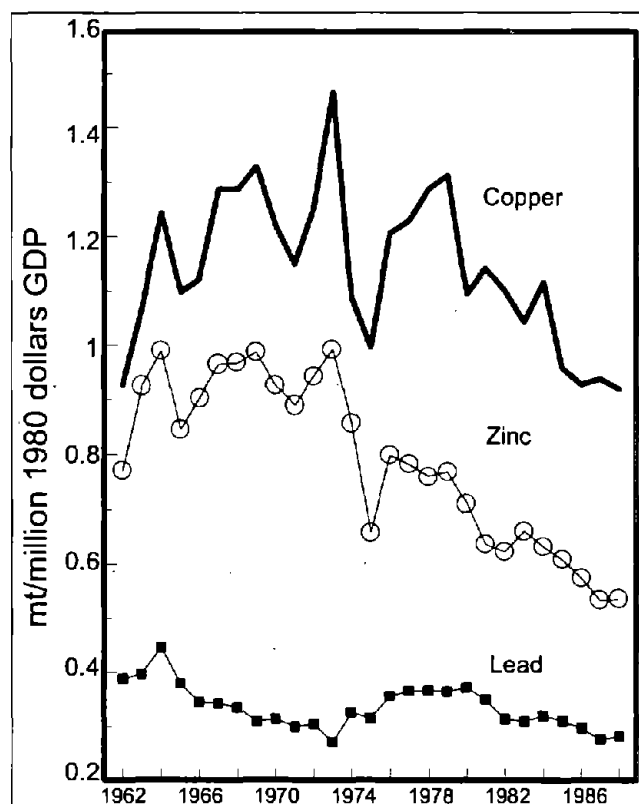


Figure 5.—Mineral intensity of use—Japan.

decline, hence the decoupling of minerals from the economy. However, as it has been observed in the previous section, although the manufacturing industry had been expanding in Japan, the services sector had changed little, with its GDP share remaining in the range of 45% to 48% during 1963-88. So the sudden change in the minerals consumption patterns in 1973 might have more to do with the national efforts to conserve raw materials than with the decoupling theory.

To sum up, Japan's minerals consumption generally grew faster than its real GDP when the economy was experienc-

ing a robust double-digit growth in the 1960's and early 1970's. After 1973, however, minerals consumption grew slower than the real GDP when the economy was expanding at a more moderate rate of about 4%. The faster growth in minerals consumption coincided with a period when the manufacturing sector was developing at a lower level, using relatively unskilled labor and nascent technology. The slower growth in minerals consumption was associated with the period when the manufacturing sector had been developing at a higher level, requiring more skilled labor and advanced technology.

## THE ASIAN NEWLY INDUSTRIALIZED COUNTRIES

According to Bradford, Jr., and Branson (1987), the first major study of the newly industrialized countries (NIC's) published by the Organization for Economic Cooperation and Development in 1979 identified the Republic of Korea, Taiwan, Hong Kong, and Singapore—also known as the Asian "Four Mini-Dragons,"—and six other countries (Brazil, Greece, Mexico, Portugal, Spain, and Yugoslavia) as NIC's based on certain economic performance criteria. The economic performance of the "Four Mini-Dragons" since then has not belied, and perhaps has exceeded, any expectations for such a designation.

### Patterns of Economic Growth and Trade

Although the Asian "Four Mini-Dragons" share the same fast lane on the economic path, they started out from two quite different economic backgrounds. Back in the 1950's, taking advantage of their central location, both Hong Kong and Singapore thrived as entrepôts of world trade, importing primary goods from neighboring countries, reexporting them to the industrialized Western countries, and trading manufactured goods in the reversed direction. The importance of entrepôt trade, however, gradually diminished as more countries started to engage in direct trade toward the end of the decade. The development strategy for the next decades thus shifted toward industrialization and exports under strict government guidance in the case of Singapore and with a minimum of government action in the case of Hong Kong.

On the other hand, the Republic of Korea and Taiwan in the 1950's were concentrating on the natural resources sector as the basis for economic development and at the same time developing light manufacturing industry primarily for import substitution. Both countries had to rely on U.S. aid for imports. Taiwan's major exports were limited to such traditional agricultural products as sugar, rice, tea, and canned pineapple. Few manufactured goods were

exported. Because of the relatively small domestic market, the import substituting strategy started to encounter difficulty toward the end of the decade as evidenced by the slower economic growth and lower capacity use rates.

The economies had reached a turning point, and a shift in economic policy was in order. Rightly, both countries shifted to an outward-looking, export-oriented strategy with a set of policy reforms. The policy change was instituted at a time when direct foreign investments (DFI) were starting to come in primarily from U.S. multinational corporations and Japanese firms seeking the comparative advantage of cheap labor available at the host countries. The DFI not only provided the much-needed capital but also brought in modern manufacturing know-how, which enabled the manufacturing industry in Taiwan and the Republic of Korea to leapfrog in technological advance and acquire capabilities to produce quality merchandise for overseas markets in a relatively short period of time. The development of export-oriented manufacturing industry helped absorb excessive rural labor, and high employment ensured a more equitable distribution of the rising income. The high saving rates and high rates of return to capital from exports enabled the countries to maintain a high level of investment, which, in turn, helped sustain the upward momentum of the economies.

The economic growth patterns of the "Four Mini-Dragons" since the decade of the 1960's have been similar and spectacular. Although the real GDP growth generally slowed down in response to the oil shocks of 1973 and 1979 and the recessions in the United States, the average growth rates for all four countries have been very high, as shown in table 1. During the 1960's, the Republic of Korea's economy grew at an annual compound rate of almost 8%, which is the smallest of the group. Taiwan's real GDP grew at an annual compound rate of 9.5%, followed by Hong Kong's 9.3% and Singapore's 8.7%. In the 1970's, despite the 1974-75 U.S. recession and the two oil shocks, Hong Kong

and Singapore were able to maintain almost the same growth rates, while the pace of growth even accelerated in the Republic of Korea and Taiwan to an annual compound rate of 9.8% and 10%, respectively. The aftermath of the second oil shock and the ensuing recession in the West caused the growth rates in the first half of the 1980's generally to drop by about one-third from the levels of the 1970's. However, with the gradual recovery in the world economies, the growth rates resumed the established trends in the last half of the 1980's with the real GDP increasing at a rate exceeding or approaching that attained in the 1970's. The real GDP growth of the "Four Mini-Dragons" is shown in figure 6.

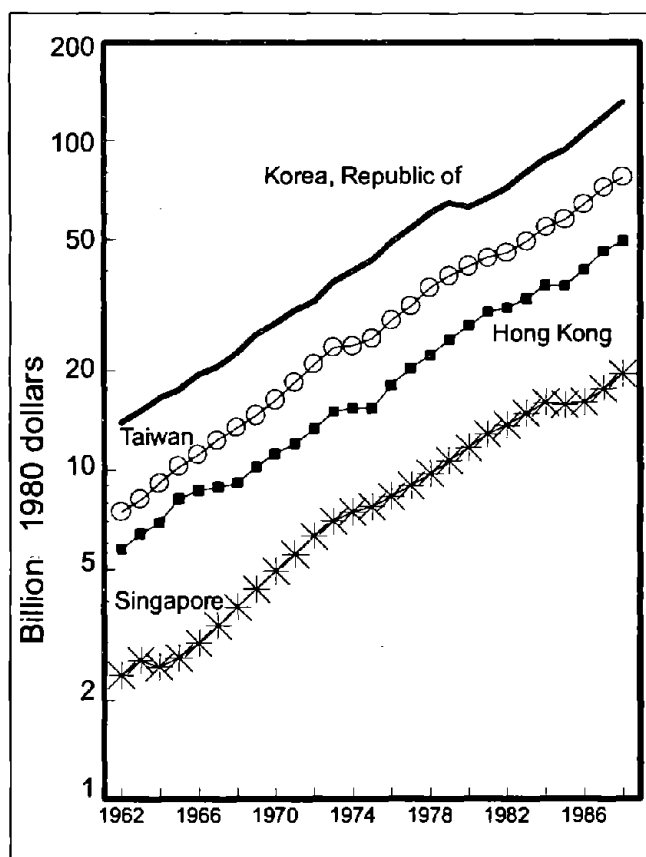


Figure 6.—GDP growth of the NIC's.

The formula for these economic successes has been to import raw materials and intermediate goods to make manufactured products for export to the industrialized countries. The result has been a change in the economic structure, with the manufacturing sector rising to dominate the other sectors. The trends are particularly clear for the Republic of Korea and Taiwan. Tables 6, 7, and 8, respectively, show the changes in the economic structure of the Republic of Korea, Taiwan, and Singapore.

After World War II, South Korea gained independence almost totally as an agrarian country without any significant industrial bases. In 1963, agriculture accounted for 42% of real GDP, and manufacturing ranked fourth behind services and trade sectors, representing only 8.2% of real GDP. By 1968, however, the manufacturing share of real GDP had almost doubled and continued to rise, reaching

Table 6.—The Republic of Korea's GDP share by major industries (In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 41.9   | 34.1   | 25.8   | 18.1   | 15.4   | 10.2   |
| Manufacturing  | 8.2    | 13.1   | 20.3   | 28.3   | 31.4   | 38.2   |
| Construction   | 3.3    | 6.0    | 6.4    | 8.5    | 8.9    | 7.8    |
| Transportation | 2.0    | 3.8    | 5.4    | 6.6    | 7.2    | 7.2    |
| Trade          | 10.5   | 12.0   | 15.0   | 13.5   | 12.6   | 13.3   |
| Services       | 31.3   | 28.2   | 24.2   | 21.8   | 21.1   | 19.5   |
| Others         | 2.8    | 2.8    | 2.9    | 3.2    | 3.4    | 3.8    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

Table 7.—Taiwan's GDP share by major industries (In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 24.0   | 19.9   | 12.1   | 8.7    | 6.7    | 4.7    |
| Manufacturing  | 19.6   | 22.8   | 32.4   | 35.1   | 37.1   | 38.2   |
| Construction   | 3.8    | 4.2    | 4.5    | 6.3    | 5.0    | 4.3    |
| Transportation | 2.8    | 3.5    | 4.5    | 5.6    | 6.6    | 6.4    |
| Trade          | 15.1   | 14.0   | 13.6   | 12.9   | 13.7   | 14.7   |
| Services       | 29.9   | 31.5   | 29.4   | 27.8   | 27.4   | 28.4   |
| Others         | 4.8    | 4.1    | 3.5    | 3.6    | 3.5    | 3.3    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

Table 8.—Singapore's GDP share by major industries (In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 3.5    | 3.0    | 2.0    | 1.5    | 1.0    | —      |
| Manufacturing  | 17.1   | 21.2   | 28.1   | 27.9   | 24.9   | 28.2   |
| Construction   | 6.7    | 8.0    | 7.3    | 6.5    | 10.5   | 5.2    |
| Transportation | 8.8    | 8.3    | 9.9    | 13.0   | 15.0   | 16.5   |
| Trade          | 29.7   | 26.7   | 23.9   | 22.7   | 20.0   | 20.3   |
| Services       | 32.2   | 30.2   | 26.4   | 25.8   | 25.9   | 26.7   |
| Others         | 2.0    | 2.6    | 2.4    | 2.6    | 2.7    | 3.1    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

— Dash denotes negligible.

Source: The World Bank.

38.2% in 1988. The GDP share of the agricultural sector, meanwhile, declined continuously to 10% in 1988. Unlike the Republic of Korea, Taiwan started off with some industrial bases, and its manufacturing share of real GDP was almost 20% in 1963. The development patterns, however, are very similar, with the manufacturing share continuing to rise and agriculture's share to fall. In 1988, Taiwan's manufacturing sector grew to account for 38.2% of real GDP, the same percentage as the Republic of Korea's.

As can be seen from table 8, the ascent of manufacturing in Singapore is also evident, although not as pronounced as in the Republic of Korea and Taiwan. The real GDP share of manufacturing in 1963 was 17.1%, only slightly lower than the 19.6% manufacturing share in Taiwan that year. In 1988, Singapore's manufacturing share of real GDP rose to 28.2%, which was 10% lower than Taiwan's. Reflecting the diminishing importance of entrepôt trade, the real GDP share of the trade sector dropped from about 30% in 1963 to about 20% in 1988. Singapore, however, like Hong Kong, also has developed into a regional financial center with the financial and business services sector contributing a large share of the real GDP. Data in table 8 showing the real GDP share of the services sector declining from 32.2% in 1963 to 26.7% in 1988 have masked this trend. The overall declines in the GDP share of the services sector were caused by "other services."

No data are available for compiling a similar table for Hong Kong, but the economic structural change in Hong Kong probably is similar to that in Singapore, although the

composition of the manufacturing industry may differ. Although manufacturing is the common strength of the economies of the Asian "Four Mini-Dragons," the industry lineup within the manufacturing sectors differs markedly between the Republic of Korea and Taiwan on one hand and Hong Kong and Singapore on the other, which could have direct implications for minerals consumption patterns. Because export dependency is very high for all four countries, such structural differences may be seen from the product composition of their exports, although for the latter group this may be less so because of the entrepôt trade. Tables 9 and 10 present the export product mix of the Republic of Korea and Taiwan in 5-year intervals for 1963-88. It is interesting that these two tables present a strikingly similar picture of changes in the export commodity mix of the two countries. In 1963, natural resource based exports accounted for more than one-half and manufacturing exports less than one-half of both countries' total exports. In the next 10 years, the Republic of Korea's manufacturing share had almost doubled, and Taiwan's had more than doubled. By 1988, the manufacturing share of exports reached around 93% in both countries, rendering other export items almost irrelevant.

During the 1960's, exports of manufactured goods were dominated by items in the SITC 6 category. The most notable were textile, leather, wood, paper, glass, and related products. Although this group has remained an important export component throughout the years in both countries, exports of miscellaneous manufactured goods in the

**Table 9.—The Republic of Korea's product composition of exports**  
(In percentages)

| SITC categories                               | Year  |       |       |       |       |       |
|-----------------------------------------------|-------|-------|-------|-------|-------|-------|
|                                               | 1963  | 1968  | 1973  | 1978  | 1983  | 1988  |
| All commodities                               | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 0. Food and live animals                      | 20.8  | 9.8   | 7.6   | 7.3   | 4.5   | 3.9   |
| 1. Beverages and tobacco                      | 0.3   | 1.9   | 0.7   | 0.9   | 0.5   | 0.2   |
| 2. Crude materials                            | 30.1  | 13.5  | 6.1   | 2.6   | 1.2   | 1.1   |
| 3. Mineral fuels and lubricants               | 3.0   | 0.5   | 1.1   | 0.3   | 2.3   | 1.0   |
| 4. Animal and vegetable oil and fats          | 0.1   | —     | —     | —     | —     | —     |
| Manufacturing (5-8)                           | 45.5  | 74.3  | 84.3  | 88.5  | 91.4  | 93.6  |
| 5. Chemicals                                  | 1.0   | 0.7   | 1.5   | 2.7   | 2.8   | 3.1   |
| 6. Manufactured goods                         | 32.4  | 31.5  | 34.2  | 29.8  | 28.5  | 20.8  |
| 7. Machinery and transportation equipment     | 4.7   | 5.4   | 12.3  | 20.3  | 32.6  | 38.6  |
| 8. Miscellaneous manufactured goods           | 7.4   | 36.7  | 36.3  | 35.7  | 27.5  | 31.1  |
| 9. Miscellaneous transactions and commodities | 0.2   | —     | 0.2   | 0.2   | 0.1   | 0.1   |

— Dash denotes negligible; the column figures may not add up to the total because of rounding.

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

**Table 10.—Taiwan's product composition of exports**  
(In percentages)

| SITC categories                               | Year  |       |       |       |       |       |
|-----------------------------------------------|-------|-------|-------|-------|-------|-------|
|                                               | 1963  | 1968  | 1973  | 1978  | 1983  | 1988  |
| All commodities                               | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 0. Food and live animals                      | 8.7   | 9.8   | 4.3   | 3.2   | 2.1   | 1.6   |
| 1. Beverages and tobacco                      | 50.6  | 21.9  | 9.7   | 7.7   | 4.9   | 3.9   |
| 2. Crude materials                            | 3.9   | 2.3   | 1.8   | 2.5   | 2.8   | 2.2   |
| 3. Mineral fuels and lubricants               | 0.3   | 0.5   | 0.1   | —     | —     | —     |
| 4. Animal and vegetable oil and fats          | —     | —     | —     | —     | —     | —     |
| Manufacturing (5-8)                           | 36.4  | 65.4  | 83.9  | 86.5  | 90.2  | 92.3  |
| 5. Chemicals                                  | 4.8   | 3.0   | 1.7   | 4.4   | 4.2   | 4.0   |
| 6. Manufactured goods                         | 28.6  | 43.8  | 42.7  | 38.5  | 36.6  | 30.1  |
| 7. Machinery and transportation equipment     | 1.8   | 13.3  | 22.8  | 23.5  | 27.2  | 36.9  |
| 8. Miscellaneous manufactured goods           | 1.2   | 5.3   | 16.7  | 20.1  | 22.2  | 21.3  |
| 9. Miscellaneous transactions and commodities | —     | —     | —     | —     | —     | —     |

— Dash denotes negligible; the column figures may not add up to the total because of rounding.

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

SITC 8 category, which include furniture, clothing, footwear, toys, and other miscellaneous consumer products, also gained importance since the late 1960's. In the Republic of Korea, exports of commodities in this category quickly exceeded those in the SITC 6 category and accounted for 31.1% of the total exports in 1988. In Taiwan, exports of miscellaneous manufactured goods also increased but at a lesser extent, accounting for only 21.3% of its total exports in 1988.

The manufactured goods included in the SITC 6 and 8 groups in general are unskilled labor intensive, and are characterized by low technological and capital contents. On the other hand, those included in the SITC 7 category, machinery and transportation equipment, are in general capital intensive, and require skilled labor and high technology. This group comprises industrial machinery, electric and electronic devices, and transportation equipment such as cars, trucks, and trains. Not surprisingly, both countries exported few manufactured goods in this category in the 1960's. However, as industrialization proceeded, the situation changed and exports of manufactured goods in this higher end of the industry increased rapidly. In 1988, they came near 40% of the total manufacturing exports in both countries.

Tables 11 and 12 present the commodity composition of exports by Hong Kong and Singapore, respectively. With no natural resources and a tiny domestic market, Hong Kong's economic survival depends on its ability to export manufactured goods to overseas markets to earn foreign

exchange. It had a head start in developing its light manufacturing industry in the 1950's, and in 1963 the manufacturing share of exports already accounted for 84.7%, the highest of the "Four Mini-Dragons" at that time. But 88% of the manufacturing exports were in the SITC 6 and 8 categories, notably, textile products, clothing, watches, clocks, and toys.

Exports of more sophisticated industrial products in the SITC 7 category represented only about 6% of the manufacturing exports. Throughout the years, commodities in the SITC 6 and 8 categories largely have remained the mainstay of Hong Kong's exports, although the relative importance of these commodities has declined gradually. In 1988, their share of manufacturing exports was 64%, down from 88% in 1963. Meanwhile, exports in the SITC 7 category increased dramatically in the 1980's, accounting for about 30% of the total manufacturing exports in 1988, up from 6% 25 years ago. The main items were electronic products such as televisions and telecommunication equipment, many of which involved assembling from imported parts only and did not reflect real manufacturing capabilities.

Singapore was a part of Malaysia during the 1950's. The major industries developed at that time were those that processed primary products such as rubber and palm and vegetable oils, which were abundantly available nearby, and those that produced beverages, clay products, and furniture. Singapore had a natural comparative advantage over imports because of its proximity to the domestic markets in

**Table 11.—Hong Kong's product composition of exports**  
(In percentages)

| SITC categories                               | Year  |       |       |       |       |       |
|-----------------------------------------------|-------|-------|-------|-------|-------|-------|
|                                               | 1963  | 1968  | 1973  | 1978  | 1983  | 1988  |
| All commodities                               | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 0. Food and live animals                      | 8.3   | 4.0   | 3.1   | 2.9   | 3.1   | 2.7   |
| 1. Beverages and tobacco                      | 1.5   | 0.4   | 0.3   | 0.3   | 0.7   | 1.2   |
| 2. Crude materials                            | 4.3   | 2.7   | 3.1   | 2.9   | 3.4   | 3.0   |
| 3. Mineral fuels and lubricants               | 0.3   | 0.4   | 0.2   | 0.4   | 0.5   | 0.4   |
| 4. Animal and vegetable oil and fats          | 0.4   | —     | —     | —     | 0.1   | 0.2   |
| Manufacturing (5-8)                           | 84.7  | 92.1  | 93.0  | 92.7  | 91.5  | 91.8  |
| 5. Chemicals                                  | 5.2   | 4.2   | 3.5   | 3.6   | 3.7   | 5.8   |
| 6. Manufactured goods                         | 25.9  | 22.3  | 22.9  | 16.6  | 15.7  | 17.8  |
| 7. Machinery and transportation equipment     | 5.0   | 9.7   | 14.1  | 16.1  | 23.0  | 26.8  |
| 8. Miscellaneous manufactured goods           | 48.6  | 55.9  | 52.4  | 56.4  | 49.1  | 41.3  |
| 9. Miscellaneous transactions and commodities | 0.5   | 0.3   | 0.3   | 0.7   | 0.6   | 0.7   |

— Dash denotes negligible; the column figures may not add to the total because of rounding.

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

**Table 12.—Singapore's product composition of exports**  
(In percentages)

| SITC categories                               | Year  |       |       |       |       |       |
|-----------------------------------------------|-------|-------|-------|-------|-------|-------|
|                                               | 1963  | 1968  | 1973  | 1978  | 1983  | 1988  |
| All commodities                               | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 0. Food and live animals                      | 16.7  | 12.9  | 6.9   | 6.5   | 4.4   | 4.2   |
| 1. Beverages and tobacco                      | 1.5   | 1.2   | 0.4   | 0.4   | 0.5   | 0.7   |
| 2. Crude materials                            | 32.1  | 28.7  | 24.2  | 15.2  | 7.3   | 5.1   |
| 3. Mineral fuels and lubricants               | 12.4  | 20.8  | 15.4  | 23.2  | 28.1  | 15.6  |
| 4. Animal and vegetable oil and fats          | 1.2   | 2.4   | 1.9   | 2.2   | 1.4   | 1.1   |
| Manufacturing (5-8)                           | 28.6  | 24.1  | 44.7  | 46.0  | 50.7  | 71.8  |
| 5. Chemicals                                  | 3.0   | 3.1   | 4.4   | 3.8   | 4.2   | 6.6   |
| 6. Manufactured goods                         | 11.8  | 10.0  | 10.3  | 9.8   | 8.0   | 8.3   |
| 7. Machinery and transportation equipment     | 9.8   | 6.5   | 22.1  | 24.9  | 31.8  | 48.0  |
| 8. Miscellaneous manufactured goods           | 4.0   | 4.5   | 7.8   | 7.5   | 6.7   | 9.0   |
| 9. Miscellaneous transactions and commodities | 7.5   | 9.9   | 6.5   | 6.5   | 7.6   | 1.5   |

Note. — The column figures may not add to the total because of rounding.

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

Malaysia. Singapore also served as a major entrepôt to reexport primary products such as rubber and coconut and palm oil from Malaysia and other neighboring countries. This is reflected in table 12 which shows that exports of the SITC 2 category, crude materials, were the largest among all commodity groups, accounting for 32.1% of total exports in 1963 and 28.7% in 1968.

However, as Singapore became an independent state in 1965 and succeeded in its export-oriented industrialization,

the importance of the entrepôt trade diminished gradually. Exports of domestically produced goods had replaced part of the reexports, and the major reexports had shifted from primary to manufactured goods. Reflecting this latter development, the crude materials exports (SITC 2 category) dropped from 32.1% of the total exports in 1963 to only 5% in 1988.

The success of industrialization is evidenced in the increases in the share of manufacturing exports from 28.6%

of the total exports in 1963 to 71.8% in 1988. The increases reflected rapid growth in machinery and transportation equipment (SITC 7), which accounted for almost 70% of the total manufacturing exports in 1988. Some of these increases were from reexports. But according to Wong (1987), the domestic exports of these industries accounted for 64.6% of the total manufacturing exports in 1982 compared to 14% in 1960, suggesting a rapid rise in the domestic industries. One aspect of industrialization in Singapore not shared by the other "Mini-Dragons" is the development of the petroleum refinery industry. As can be seen from table 12, exports of mineral fuels (SITC 3 category) represented 12.4% of the total exports in 1963, and the share rose to 15.6% in 1988. These figures, however, belie the emergence of the domestic petroleum refinery industry as those in the 1960's reflected mostly reexports of imported crude oil and those in the 1980's comprised mostly direct exports of domestically refined petroleum products.

Another unique aspect of Singapore's industrialization is the high rate of foreign firm participation. Because many foreign direct investments took the form of moving manufacturing operations offshore with domestically produced parts, Singapore's manufactured goods are in general very high in import content (Wong, 1987). Partly for this reason, the industrial development in Singapore, like in Hong Kong, has not required proportionally as much mineral consumption as in the Republic of Korea and Taiwan.

### Patterns of Minerals Consumption

Although Hong Kong and Singapore both enjoyed economic growth that was as fast as economic growth in the Republic of Korea and Taiwan, because of their entrepôt background, specialization in financial services, and concentration in light manufacturing industry, their consumption of minerals has been only a fraction of that of South Korea and Taiwan. Perhaps because of this, most of their metal consumption data are not available except for aluminum and zinc. Data for metals consumption are presented in appendix tables A-1 through A-8. As can be seen from these tables, in 1988, Hong Kong consumed only 33,600 metric tons of primary aluminum and about 25,000 tons of zinc, while Singapore's consumption was only about one-half of those. In comparison, the Republic of Korea and Taiwan consumed 268,000 and 176,000 tons of aluminum and 173,000 and 74,000 metric tons of zinc, respectively, in the same year.

The consumption of aluminum and zinc by Hong Kong and Singapore is plotted along with GDP growth in figures 7 and 8, respectively. During the first half of the 1980's, affected by the second oil crisis and the worldwide recession, minerals consumption decreased in the first half of the

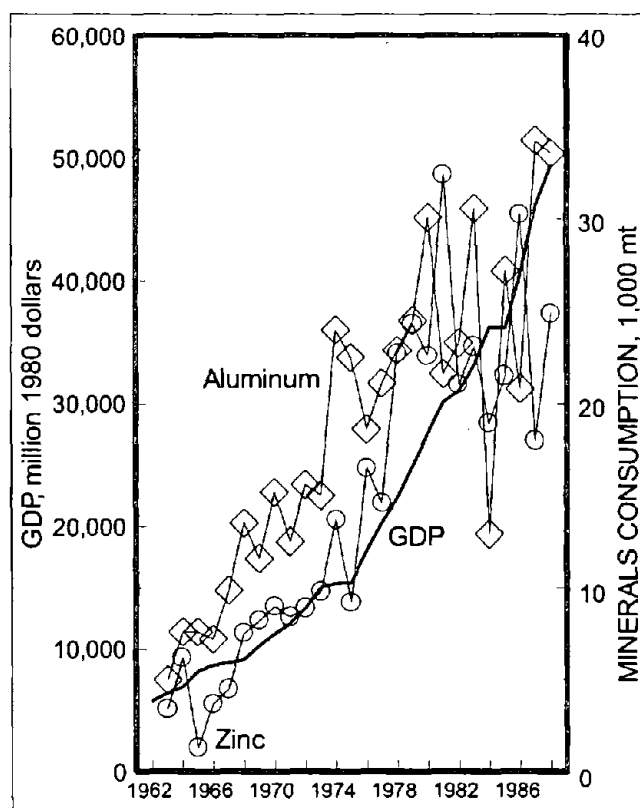


Figure 7.—GDP growth and mineral consumption—Hong Kong.

1980's in both countries, but their GDP growth did not seem to have been affected as much, as other key sectors such as financial services provided strength. On the other hand, minerals played a far more important role in the economic development of both the Republic of Korea and Taiwan. This can be seen from table 13, compiled from the consumption data in the appendix tables. In 1970, Taiwan and the Republic of Korea consumed only 34,200 and 15,300 metric tons of primary aluminum, respectively, which was only a fraction of the Japanese consumption of over 910,000 tons. But after 1970 aluminum consumption in-

Table 13.—Consumption of major nonferrous metals—the NIC's

(Annual compound growth rate in percentages for 1970-88)

| Country           | Minerals          |                   |      |      |
|-------------------|-------------------|-------------------|------|------|
|                   | Aluminum          | Copper            | Zinc | Lead |
| Republic of Korea | 17.2              | <sup>1</sup> 18.2 | 16.5 | 17.5 |
| Taiwan            | 9.5               | <sup>1</sup> 18.9 | 9.4  | 15.0 |
| Hong Kong         | 4.5               | —                 | 5.8  | —    |
| Singapore         | <sup>2</sup> 14.7 | —                 | 4.1  | —    |

Note.—Dash denotes negligible.

<sup>1</sup>1971-89.

<sup>2</sup>1977-88.

Source: Metal Statistics.

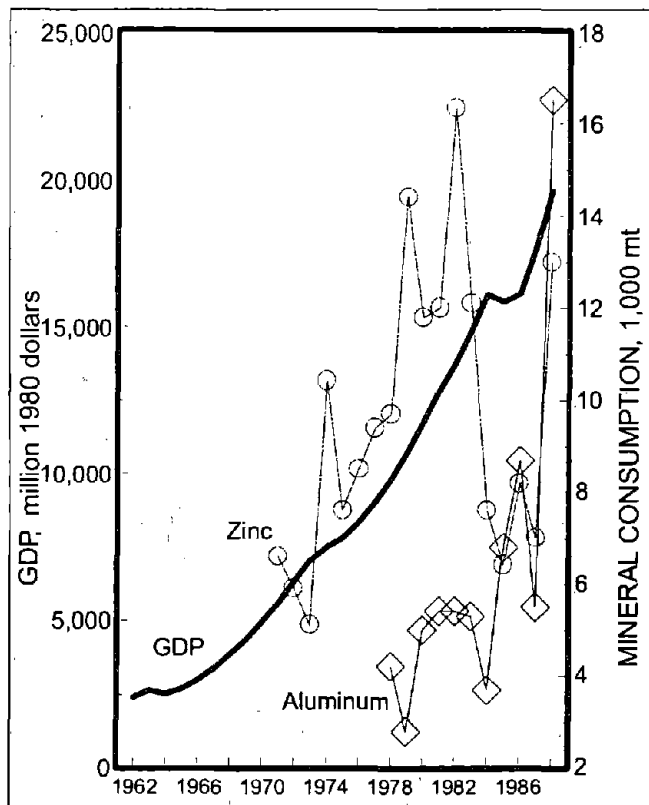


Figure 8.—GDP growth and mineral consumption—Singapore.

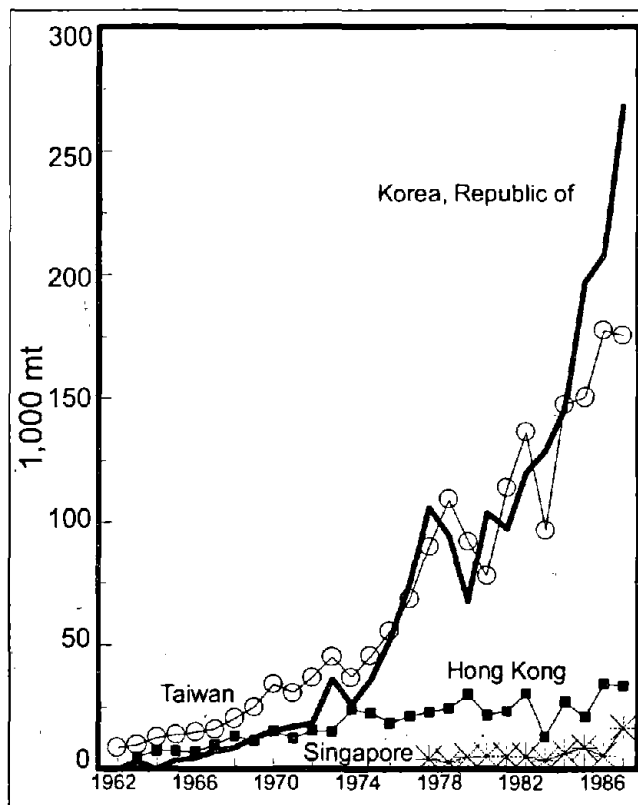


Figure 9.—Primary aluminum consumption—The NIC's.

creased at an annual compound rate of 17.2% in the Republic of Korea, reaching 268,000 tons in 1988. Taiwan's aluminum consumption increased at a relatively moderate rate of 9.5%, partly because of the higher base, and reached 176,000 tons in 1988. The annual aluminum consumption of both countries is plotted along with that of Hong Kong and Singapore in figure 9. Again, the consumption patterns of the Republic of Korea and Taiwan appear very similar, with a steep increase in the 1980's.

The increases in copper consumption in the Republic of Korea and Taiwan followed a similar pattern. In 1971, each country consumed only about 8,000 metric tons of refined copper, which was only one-hundredth of the Japanese consumption. However, by 1988, copper consumption soared to 207,000 tons in both countries, reflecting an annual compound growth rate of over 18%, an amount about 16% of the Japanese consumption. These consumption patterns are shown in figure 10. The steeper increases in copper consumption since 1982 reflected the rise of the copper rod and wire mills in both countries to cater to the increasing domestic needs and foreign demands.

Zinc consumption data are available for all four Asian NIC's. The four countries' zinc consumption patterns are plotted in figure 11 in a logarithmic scale to accommodate the wide numeric variations in the data. Zinc consumption in the Asian NIC's was minimal during the 1960's, amount-

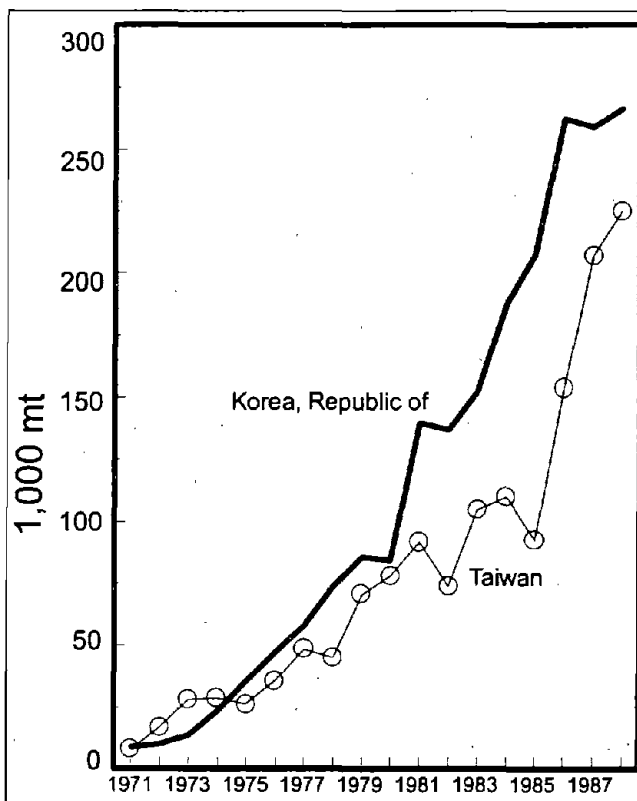


Figure 10.—Refined copper consumption—The NIC's.

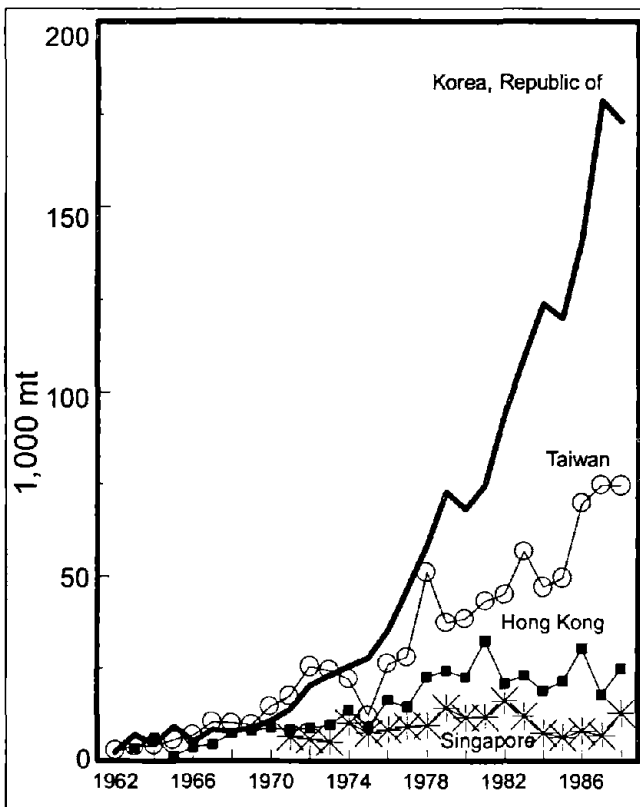


Figure 11.—Zinc consumption—the NIC's.

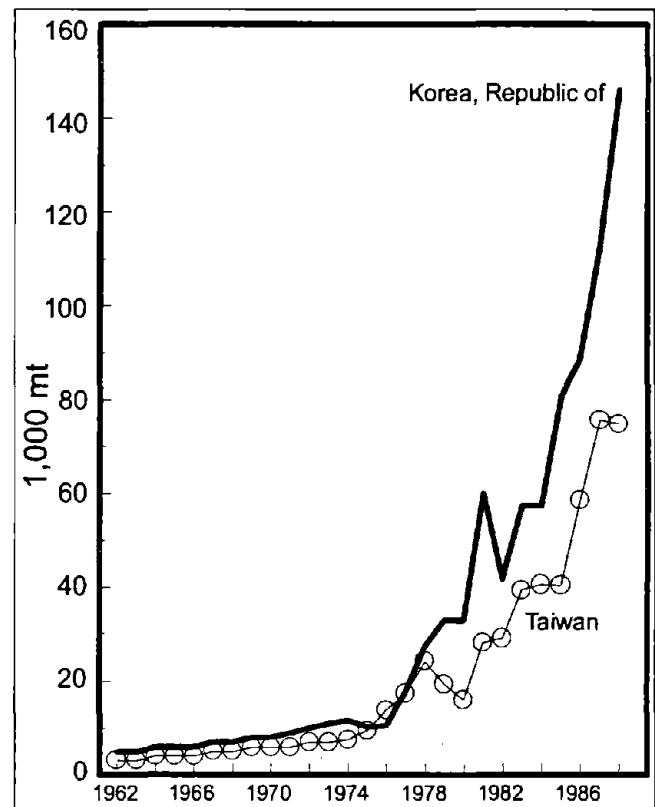


Figure 12.—Lead consumption—the NIC's.

ing to only several thousand tons in each country. In 1970, zinc consumption in Taiwan and the Republic of Korea was just over 10,000 metric tons, and that of Hong Kong and Singapore was even lower. The divergences in the consumption patterns after 1970 reflected clearly the different paths of industrialization pursued by the four countries. Zinc consumption increased at an annual rate of 16.5% in South Korea and 9.4% in Taiwan in the 1970-88 period, compared to only about 6% in Hong Kong and 4% in Singapore. In 1988, the consumption levels reached 173,000 tons in the Republic of Korea and 74,400 metric tons in Taiwan but remained 25,000 metric tons in Hong Kong and 13,000 metric tons in Singapore—the levels almost unchanged during the 1980's. The Republic of Korea's zinc consumption was almost the same as that of Taiwan in the late 1960's, but 20 years later, the Republic of Korea was consuming twice as much as Taiwan. This is also true of lead consumption which is graphed in figure 12.

In 1970, the Republic of Korea and Taiwan consumed 8,000 and 6,000 metric tons of lead, respectively. The increases in lead consumption in the Republic of Korea after 1970 outpaced those in Taiwan to reach 146,000 tons in 1988, twice the amount of Taiwan's consumption. As can be seen from figures 9-12, the Republic of Korea has

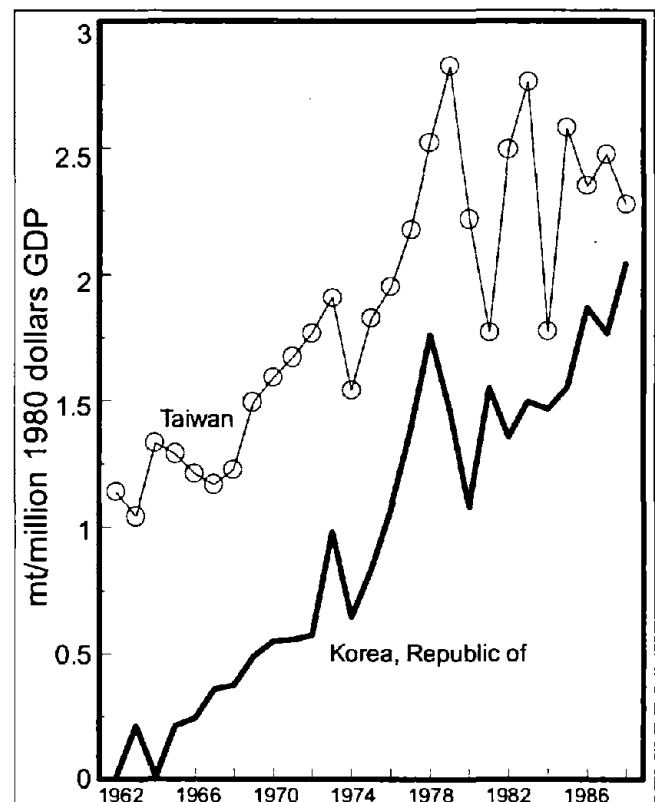


Figure 13.—Aluminum intensity of use—the NIC's.

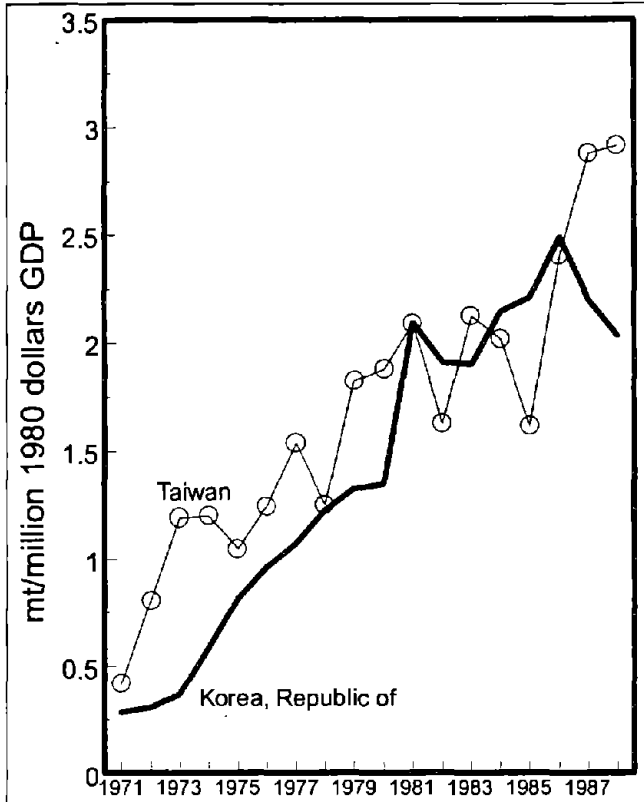


Figure 14—Copper intensity of use—the NIC's.

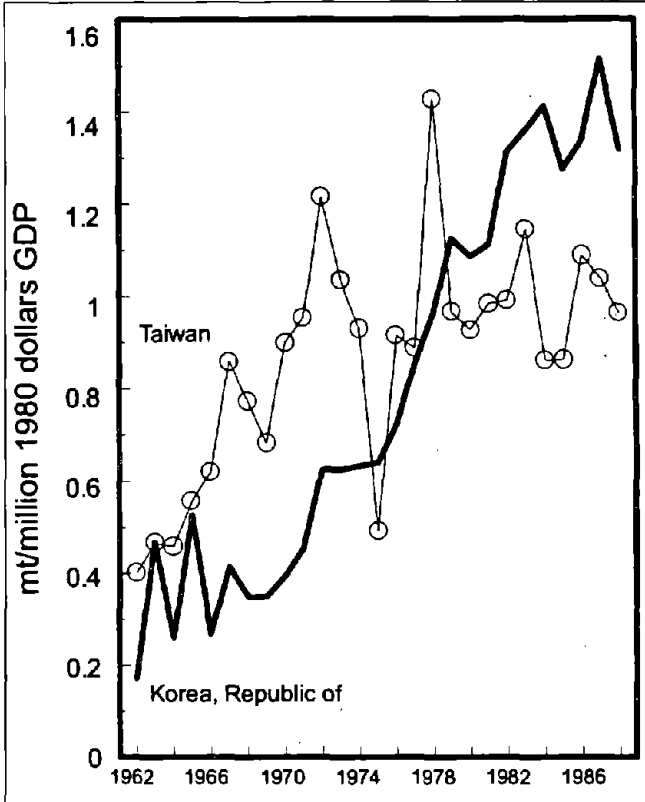


Figure 15.—Zinc intensity of use—the NIC's.

generally consumed larger quantities of the four metals than Taiwan since the early 1970's, with the consumption gaps widening further since the early 1980's. (Since 1982, South Korea's consumption is larger by 17% in aluminum, 14% in copper, 125% in zinc, and 62% in lead.) However, the Republic of Korea has a population twice as large as Taiwan's, and its 1988 GDP was about 30% larger. So a more meaningful comparison would be by the measures of GDP-based mineral intensity of use. Figures 13-16 present the graphs of these measures for both countries.

Overall, Taiwan has had higher aluminum use intensity all along, while the Republic of Korea has been higher in zinc use intensity since 1979. This is because Taiwan started out with some aluminum and zinc smelting capabilities after World War II, while the Republic of Korea had virtually no such industrial bases at that time. Both countries seem to have about the same levels of use intensity of copper and lead. These figures also indicate that both countries' mineral use intensities were in general still on the rise during the 1980's in contrast with Japan's, which have been declining since 1973. (See figures 4 and 5.) Overall, reflecting the similarity in economic growth and industrial structure, the Republic of Korea and Taiwan have comparable patterns of minerals consumption.

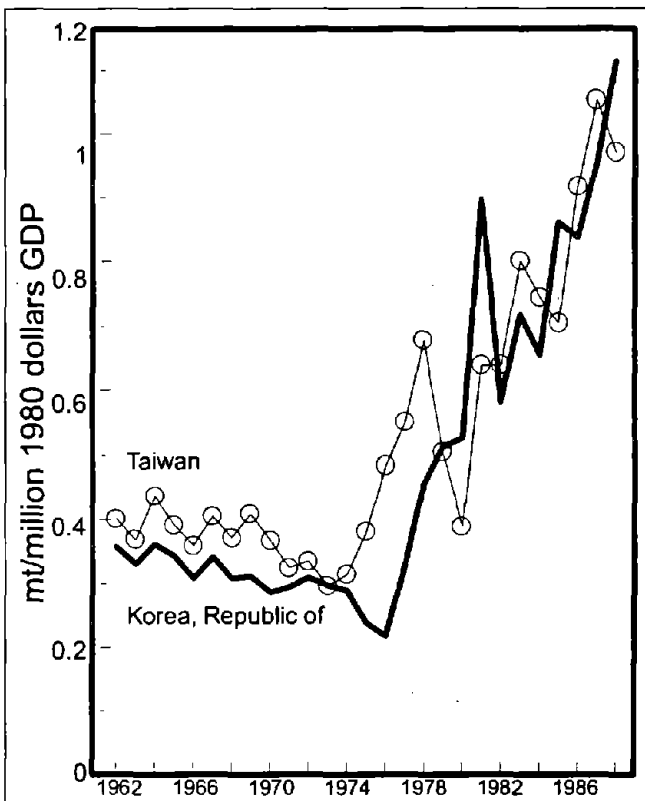


Figure 16.—Lead intensity of use—the NIC's.

## THE ASEAN FOUR

### Patterns of Economic Growth and Trade

Generally considered the next tier of the NICs, the ASEAN Four, which includes Thailand, Malaysia, the Philippines, and Indonesia, have shown a strong economic growth during the last two decades that is only slightly lower than that of the "Four Mini-Dragons." For instance, Indonesia, with a per capita income of \$530 in 1981, is classified by the World Bank as a "lower middle income" country. Its economic growth during the 1970's, as shown on table 1 averaged an annual compound rate of 7.7%, which was about two points lower than that of the "Four Mini-Dragons" but 40% higher than the average of all middle-income countries (Beals, 1987). As can be seen from figure 17, the rate of economic growth among the four countries has been very similar, with the exception of the Philippines, which experienced a sharp downturn in the first half of the 1980's. The similarity in the overall economic performance, however, masks the wide differences in sectoral development and in the pace with which the progress is being made toward industrialization.

The Philippines was severely hit by the second oil shock of 1979 and the ensuing worldwide recessions in the early 1980's.

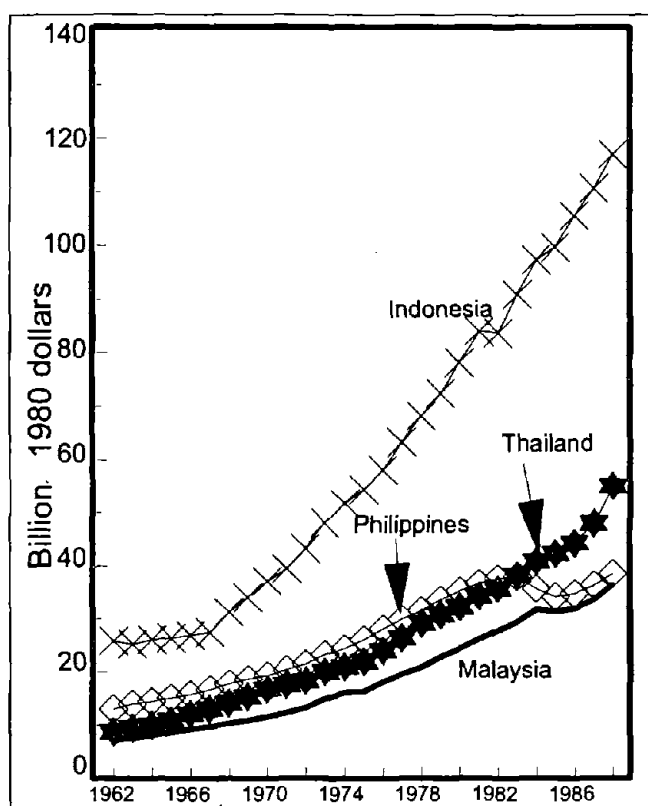


Figure 17—GDP growth of the ASEAN Four.

The political turmoil following the Aquino assassination in 1983 further slowed the economic recovery, with the result that the real GDP has been surpassed by Thailand since 1983.

The Philippines was the most industrialized among the ASEAN Four immediately after World War II, with the manufacturing sector accounting for about 20% of the real GDP in 1963. The major manufacturing industries were food processing, beverage, and tobacco in the 1950's, which were joined by chemical and basic metals in the 1960's and machinery in the 1970's. As shown in table 14, the Philippines' economic structure has changed little in the past 25 years. The manufacturing sector's share of real GDP peaked in 1973 at 25.4% and declined to 24.3% in 1988.

Table 14.—The Philippines' GDP share by major industries  
(In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 28.5   | 27.4   | 25.4   | 23.8   | 22.7   | 25.0   |
| Manufacturing  | 19.6   | 21.9   | 25.4   | 24.8   | 24.5   | 24.3   |
| Construction   | 5.7    | 4.1    | 4.1    | 7.5    | 8.1    | 4.5    |
| Transportation | 4.1    | 4.6    | 5.9    | 6.5    | 6.3    | 6.5    |
| Trade          | 27.0   | 27.5   | 23.6   | 23.2   | 24.4   | 17.9   |
| Services       | 12.7   | 11.6   | 11.8   | 10.3   | 10.1   | 17.6   |
| Others         | 2.4    | 2.9    | 3.8    | 3.9    | 3.9    | 4.2    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

The Philippines' exports had increased during the 1970's and the 1980's. In the 1970's, major export items were textiles and clothing, footwear, furniture, nonmetallic mineral manufactures, and handicrafts, but in the 1980's electronic equipment gained increasing importance in the product mix of exports. This is reflected by the data on tables 15 and 16. Table 15 shows that the Philippines' manufacturing share of exports was negligible in the 1960's and accounted for only 17.4% in 1973. The share increased

Table 15.—The shares of manufacturing exports  
in total exports—the ASEAN Four  
(In percentages)

| Country     | Year |      |      |      |      |      |
|-------------|------|------|------|------|------|------|
|             | 1963 | 1968 | 1973 | 1978 | 1983 | 1988 |
| Thailand    | 24.8 | 14.3 | 22.7 | 30.6 | 35.2 | 55.9 |
| Malaysia    | 29.1 | 33.7 | 30.7 | 30.7 | 30.2 | 41.5 |
| Philippines | 4.6  | 6.8  | 17.4 | 22.2 | 26.6 | 36.8 |
| Indonesia   | 1.1  | 18.6 | 4.8  | 4.2  | 8.6  | 30.7 |

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

**Table 16.—The shares of SITC 7 exports in total manufacturing exports—the ASEAN Four**  
(In percentages)

| Country     | Year |      |      |      |      |      |
|-------------|------|------|------|------|------|------|
|             | 1963 | 1968 | 1973 | 1978 | 1983 | 1988 |
| Thailand    | 1.5  | 0.5  | 1.1  | 10.9 | 16.5 | 28.3 |
| Malaysia    | 6.6  | 6.5  | 34.6 | 34.6 | 57.2 | 62.3 |
| Philippines | 0.2  | 0.3  | 1.4  | 10.0 | 19.2 | 26.3 |
| Indonesia   | 9.1  | 5.3  | 15.7 | 14.5 | 7.3  | 2.1  |

Source: U.N. Statistical Yearbook for Asia and the Pacific, various issues.

gradually in the early 1980's and dramatically in the last half of the 1980's, reaching 36.8% in 1988. Table 16 shows that the major strength of the manufacturing exports had come from exports of the SITC 7 category, which, in this case, comprised mostly electronic equipment. Export of SITC 7 items accounted for only 1.4% of the Philippines' manufacturing exports in 1973 but increased to 26.3% in 1988. However, the electronic equipment industry in the Philippines, like in Hong Kong, has involved mostly assembling operations and not many manufacturing activities.

Resource-rich Indonesia, on the other hand, was the least industrialized of the ASEAN Four back in the 1960's. As shown in table 17, more than half of its real GDP came from agriculture and mining (included in the "Others" category) in the 1960's, with the manufacturing sector contributing only about 7% to 8%. The pace of industrialization quickened after the present Government of Suharto came to power in 1966. The Government adopted the "New Order," a new economic policy to liberalize trade and foreign exchange and to encourage foreign investment. According

**Table 17.—Indonesia's GDP share by major industries**  
(In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 36.5   | 35.7   | 29.5   | 24.1   | 22.3   | 20.6   |
| Manufacturing  | 7.7    | 6.9    | 7.8    | 10.4   | 15.1   | 21.6   |
| Construction   | 1.5    | 1.7    | 3.2    | 4.6    | 5.4    | 4.8    |
| Transportation | 3.3    | 2.8    | 3.2    | 4.4    | 5.5    | 5.4    |
| Trade          | 14.2   | 13.6   | 14.5   | 14.0   | 14.5   | 15.5   |
| Services       | 19.6   | 18.0   | 11.5   | 15.3   | 17.0   | 16.4   |
| Others         | 17.2   | 21.3   | 30.4   | 27.2   | 20.2   | 15.7   |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

to Beals (1987), "Manufacturing output increased at 13.9% per annum for 1970-81 . . .," which undoubtedly was the main force behind the 7.7% annual growth of the real GDP

in that decade. The manufacturing share of real GDP continued to rise and doubled in 10 years to 21.6% in 1988. This manufacturing share of real GDP, however, was the smallest of the ASEAN Four, reflecting a relatively slower pace of industrialization in Indonesia because of her comparative advantage in natural resource development. Thus, even the manufacturing sector has been weighted considerably by resource-base industries such as plywood manufacturing, ore mining, and smelting.

As can be seen from table 15, Indonesia's manufacturing industry thus far has been geared more toward import substitution than toward exports. The export share of manufacturing goods had been very low for the past two decades and rose sharply only in recent years. In 1988, it accounted for about one-third of total exports, a ratio still the smallest of the four countries. The main export products were plywood (SITC 6 category) and clothing (SITC 8 category). Exports of the SITC 7 category in the manufacturing exports had been negligible, representing only 2% in 1988.

Malaysia, with a current population of about 16 million and per capita income of about \$2,200 (in 1980 dollars), is the least populous but the wealthiest of the ASEAN Four. After its independence in 1957, the Government implemented a number of programs to promote industrialization to diversify from a resource-based economy. As a result, the manufacturing sector grew at an average annual rate of 12% during the 1960's and 1970's (Lim, 1987), about twice the rates of the real GDP growth. The manufacturing sector's share of the real GDP, as shown in table 18, rose gradually from 8.5% in 1961 to 25.6% in 1988, while the agriculture and mining (included in the "Others" category) sectors' share declined from about one-half to one-third of the real GDP during the same period.

**Table 18.—Malaysia's GDP share by major industries**  
(In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1961   | 1965   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 38.5   | 31.0   | 27.8   | 24.0   | 20.2   | 20.1   |
| Manufacturing  | 8.5    | 10.2   | 17.2   | 19.9   | 20.5   | 25.6   |
| Construction   | 3.4    | 4.1    | 4.0    | 4.0    | 5.2    | 3.1    |
| Transportation | 4.9    | 5.0    | 3.7    | 4.6    | 5.4    | 6.1    |
| Trade          | 19.2   | 18.2   | 10.4   | 10.1   | 11.3   | 9.7    |
| Services       | 18.2   | 21.3   | 22.8   | 24.4   | 24.8   | 22.0   |
| Others         | 7.3    | 10.2   | 14.1   | 13.0   | 12.6   | 13.4   |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

<sup>1</sup>Indicates including hotels and restaurants.

Sources: For 1973-88 from the World Bank. For 1961-65 from P.C. Lim (1987, p. 439).

The major industries developed in the 1960's and 1970's, were resource based, notably food processing, beverage, tobacco, wearing apparel, wood and cork, furniture, and

rubber and rubber products. However, a rich domestic market, as reflected in the relatively high per capita income, had allowed consumer durable industries such as automobile manufacturing to develop as well. Other nonresource-based industries, such as electrical and electronic machinery, were encouraged by the establishment of a Free-Trade Zone. These industries, however, were not a large contributor to the value added (real GDP), as most of them involved assembling of imported parts and components only.

Although intended primarily for import substitution, Malaysia's manufacturing industries, especially resource-based industries, also boast a long history of exporting to overseas markets. As shown on table 15, Malaysia's exports of manufactured goods had consistently accounted for about 30% of the total exports in the 1960's and 1970's. The percentages were the highest of the ASEAN Four until 1983, when they were surpassed by Thailand's. As with other ASEAN countries, Malaysia's manufacturing exports expanded further in the last half of the 1980's, reaching 41% of the total exports in 1988. Most of the manufacturing exports were in the SITC 6 category, composed of processed goods, but as shown on table 16, exports of machinery and transportation equipment (SITC 7 category) had risen dramatically to account for about one-third of manufacturing exports in the 1970's and almost two-thirds in 1988, reflecting a remarkable shift in the manufacturing sector toward capital-intensive, technology-oriented industries.

Thailand has a current population of 56 million, a size comparable with that of the Philippines (60 million). The 1989 per capita GDP, however, is \$1,100 (in 1980 constant dollars), about 60% higher than that of the Philippines. Thailand is blessed with abundant raw materials and cheap labor. After the Government implemented the 1960 Investment Promotion Act, which exempted tax on capital goods such as machinery imported for production purposes, Thailand's manufacturing output increased by an average annual rate of 10.3% (Ajanant, 1987) and the real GDP increased by an annual compound rate of 8% during the 1960's, the highest of the four countries. As can be seen from table 1 and figure 17, Thailand's economy has recently surged ahead of other ASEAN countries, registering a compound growth rate of nearly 10% in 1985-88, comparable to that of the Republic of Korea and Taiwan. The major industries developed earlier were limited to food processing and other resource-based manufacturing but later included textile and clothing as well as machinery and transportation equipment.

Table 19 shows the transformation of Thailand's economy as a result of the past three decades of development. Agriculture was the largest sector, accounting for almost 40% of the GDP in 1963, but its share of the GDP steadily declined

**Table 19.—Thailand's GDP share by major industries**  
(In percentages)

| Industry       | Year   |        |        |        |        |        |
|----------------|--------|--------|--------|--------|--------|--------|
|                | 1963   | 1968   | 1973   | 1978   | 1983   | 1988   |
| Agriculture    | 38.2   | 32.1   | 28.4   | 25.7   | 22.2   | 19.0   |
| Manufacturing  | 12.6   | 14.1   | 19.0   | 21.0   | 21.2   | 22.8   |
| Construction   | 5.7    | 7.2    | 4.9    | 5.7    | 5.2    | 5.0    |
| Transportation | 6.1    | 5.7    | 5.4    | 5.0    | 5.9    | 6.1    |
| Trade          | 16.0   | 17.2   | 16.6   | 16.6   | 16.0   | 17.0   |
| Services       | 18.0   | 18.8   | 21.9   | 21.7   | 25.5   | 25.6   |
| Others         | 3.4    | 4.9    | 3.8    | 4.3    | 4.0    | 4.5    |
| Total          | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Source: The World Bank.

to 19% in 1988. The largest gains were made in the manufacturing and services sectors: The manufacturing sector's share of the GDP increased about 10%, and the services sector increased 7% in the 1963-88 period. In 1988, Thailand's GDP share of the manufacturing sector was 22.8%, which was in line with those of the other ASEAN countries. The expansion of the services sector to become the largest, accounting for 25.6% of the GDP in 1988, however, was a development not seen in the other ASEAN countries. In a sense, this may be reflecting the higher level of modernization and sophistication that Thailand's economy has achieved.

In fact, the GDP share of the manufacturing sector belies the importance of that sector. This can be seen from tables 15 and 16, which show that not only had Thailand's exports of manufactured goods consistently increased over the years—reaching 56% of the total exports in 1988, the highest percentage of the ASEAN Four—but the share of exports of the SITC 7 category also had risen dramatically from 1% of the total manufacturing exports in 1973 to 28% in 1988. On a current dollar basis, Thailand's machinery and transportation equipment exports had increased 19 times in the 1978-88 period. In comparison, the Philippines' equipment exports increased ninefold, Malaysia's sixfold, and Indonesia's twofold in the same period.

### Patterns of Minerals Consumption

The minerals consumption data for the ASEAN Four are presented in appendix tables A-1 through A-4 and for mineral intensity of use in appendix tables A-5 through A-8.

Table 20 summarizes the growth of minerals consumption by the ASEAN Four in annual compound rate for various time periods. The consumption patterns are generally in line with the economic growth in each country. Except for the Philippines, all three countries registered large consumption growth rates. Many double-digit growth rates, even larger than those of Taiwan and South Korea,

**Table 20.—Consumption of major nonferrous metals—  
ASEAN Four**  
(Annual compound growth rate in percentage)

| Country     | Metals                |                     |                   |                   |
|-------------|-----------------------|---------------------|-------------------|-------------------|
|             | Aluminum<br>(1970-87) | Copper<br>(1978-88) | Zinc<br>(1971-88) | Lead<br>(1975-88) |
| Thailand    | 12.7                  | 20.9                | 7.5               | 9.8               |
| Malaysia    | 18.8                  | 78.2                | 14.3              | NA                |
| Philippines | -0.5                  | 7.3                 | 3.6               | 1.5               |
| Indonesia   | 44.9                  | 122.9               | 11.7              | 11.5              |

NA Not available.

<sup>1</sup>1979-88.

Source: Metal Statistics.

are due to the extremely low bases from which they are calculated. In terms of the absolute level of consumption, the ASEAN Four are still far behind Taiwan and the Republic of Korea.

The patterns of aluminum consumption by the ASEAN Four are graphed in figure 18. As can be seen, Thailand has been the top user of aluminum, with consumption steadily increasing from 10,000 tons in 1971 to 65,000 tons in 1983. Indonesia's aluminum consumption grew slowly in

the 1970's but rapidly in the 1980's. It increased from about 12,000 tons in 1977 to 68,000 tons in 1987 and is comparable to the rapid growth experienced by Thailand in the 1973-83 period. Malaysia's aluminum consumption also followed a similar pattern, starting from a negligible amount in the early 1970's and growing to 41,000 tons in 1983. The Philippines' aluminum consumption increased from 10,000 tons in 1971 to 28,000 tons in 1979 but since then has decreased to 9,600 tons in 1988. In terms of aluminum intensity, as shown in figure 19, Thailand leads the group, followed by Malaysia, Indonesia, and the Philippines. The aluminum use intensity exhibits an upward long-run trend in all countries except the Philippines.

The ASEAN Four consumed little copper in the late 1970's. The Philippines and Thailand consumed only about 5,000 tons and Malaysia and Indonesia about 100 tons in 1978. Except for the Philippines, copper consumption by each of the three countries increased to about 30,000 tons in 1988, representing an annual compound growth rate of 78% for Malaysia and about 20% for Thailand and Indonesia. As depicted in figure 20, copper consumption in these countries historically did not increase smoothly. In Indonesia, it soared in the late 1970's. In Malaysia, Thailand, and the Philippines, it suddenly jumped up in 1983. There was

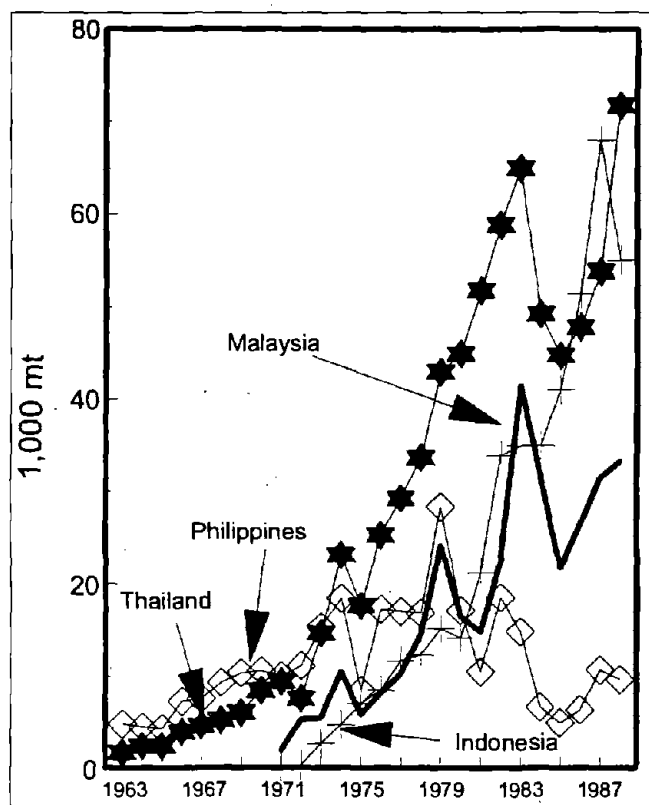


**Figure 18.—Primary aluminum consumption—the ASEAN Four.**

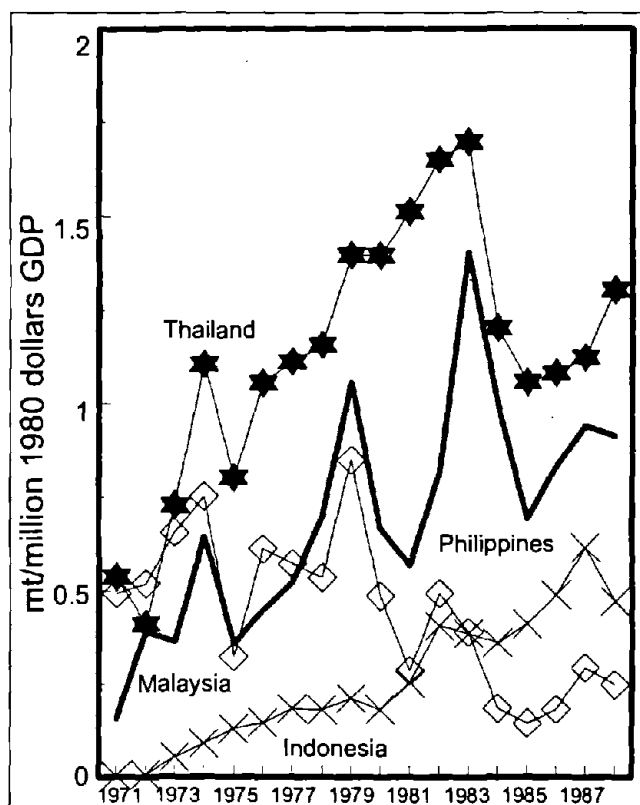


**Figure 19.—Aluminum intensity of use—the ASEAN Four.**

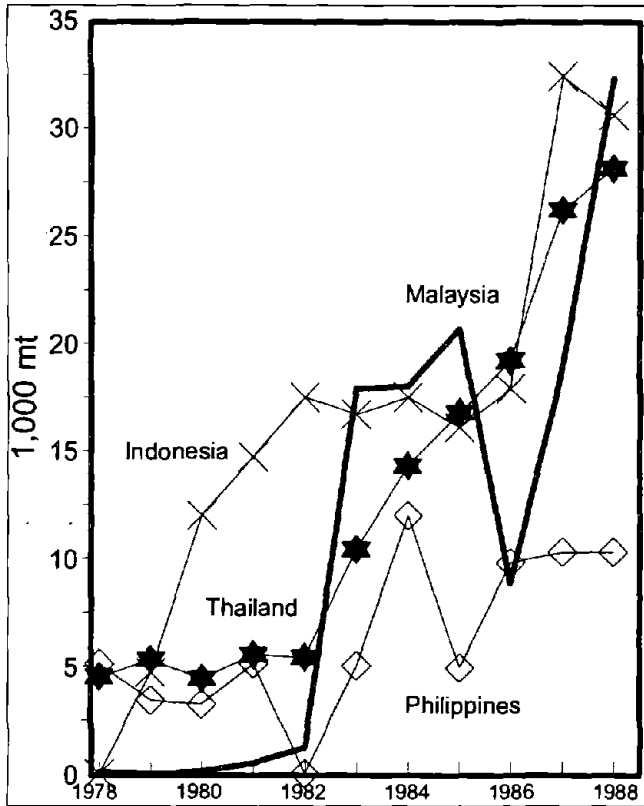


Figure 20.—Copper consumption—the ASEAN Four.

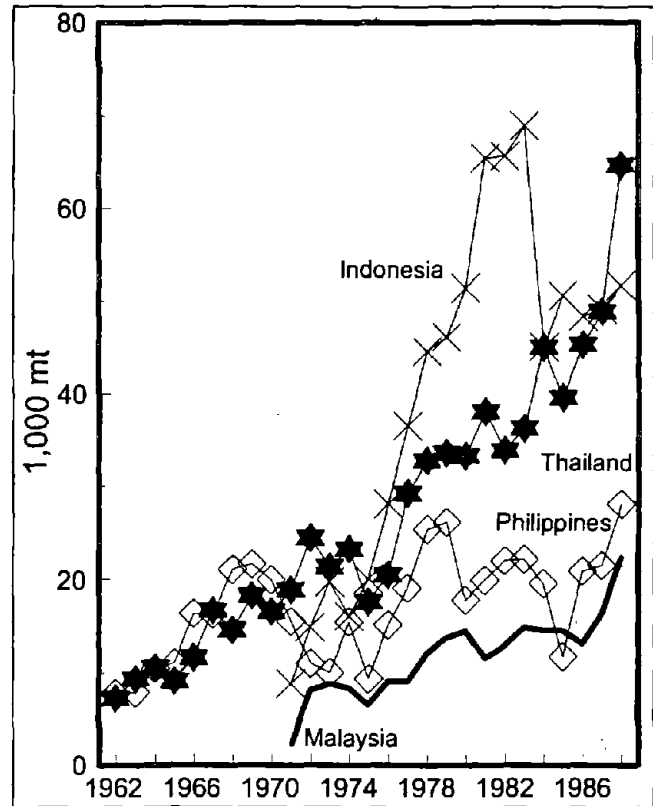


Figure 22.—Zinc consumption—the ASEAN Four.

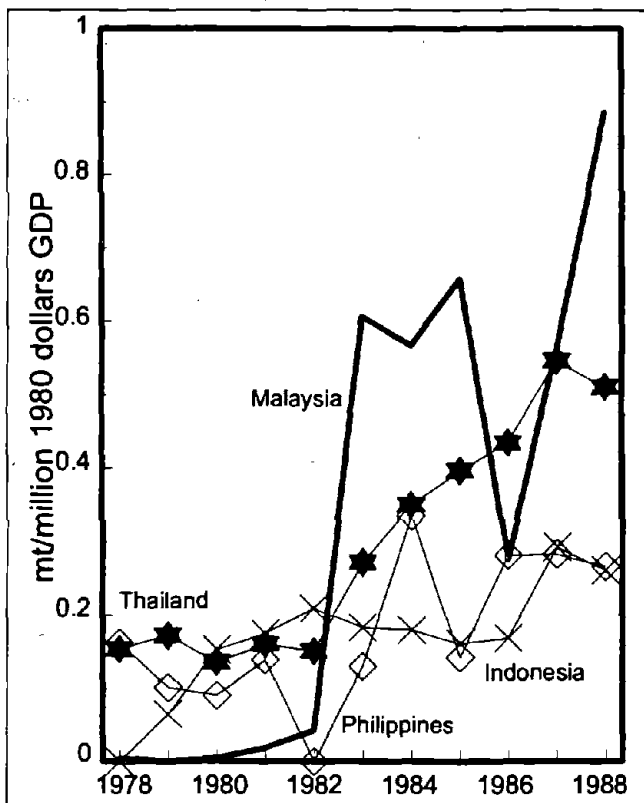


Figure 21.—Copper intensity of use—the ASEAN Four.

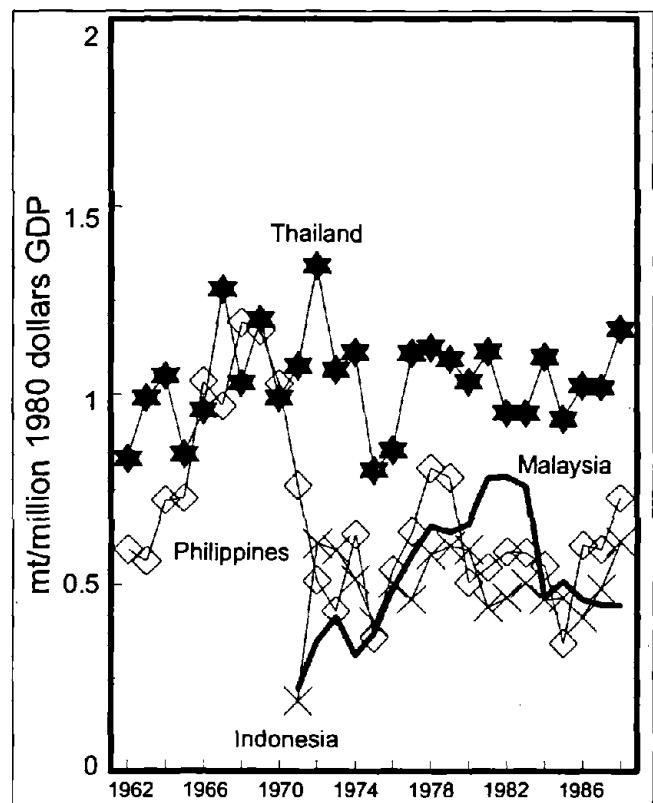


Figure 23.—Zinc intensity of use—the ASEAN Four.

another surge in 1987 in all countries except the Philippines. All these increases can be explained largely by the waves of investment in copper wire and copper rod mills made jointly with foreigners, notably the Japanese. The patterns of copper use intensity are graphed in figure 21, which in general parallel the consumption patterns shown in figure 20.

Zinc consumption by the ASEAN Four is graphed in figure 22 for 1971-88. Again, all four countries used little zinc in 1971. Thailand's consumption of about 20,000 tons was the largest in 1971, while Malaysia's consumption of 2,000 tons was the smallest. Indonesia's consumption increased most rapidly from 9,000 to 69,000 tons in 1983 and then fell sharply in 1984. On the other hand, Thailand's consumption increased steadily over the years and surpassed Indonesia's in 1988.

Zinc consumption by the Philippines and Malaysia also increased but at a very modest rate, reaching 27,000 and 22,000 tons, respectively, in 1988.

The patterns of zinc use intensity, as shown in figure 23, zigzagged in a relatively narrow range, showing no trends.

Lead consumption by three of the ASEAN Four, for which data are available, is presented for 1975-88 in figure 24. Lead consumption increased very slowly until 1981-82. By then all three countries each consumed about 10,000 tons of lead. Thailand again led the others, with its consumption soaring from about 10,000 tons to 27,000 tons in 1981-88, representing an average annual growth rate of 24%. Lead consumption by Indonesia and the Philippines increased at a slower rate, reaching 16,000 and 12,000 tons, respectively, in 1988.

The patterns of lead use intensity are presented in figure 25, which indicates that Thailand and the Philippines had about the same level of lead use intensity until 1981, but since then Thailand has surpassed the Philippines. Indonesia is a distant third. The lead use intensities of Thailand and Indonesia show a moderate long-run upward trend, but that of the Philippines exhibits no trends.

## MODELS OF MINERALS DEMAND AND ECONOMIC DEVELOPMENT

The purpose of this section is to develop models to describe the relationships between minerals demand and economic development in the Asian Pacific Rim econo-

mies. As a background for such a model development, a brief literature review is in order.

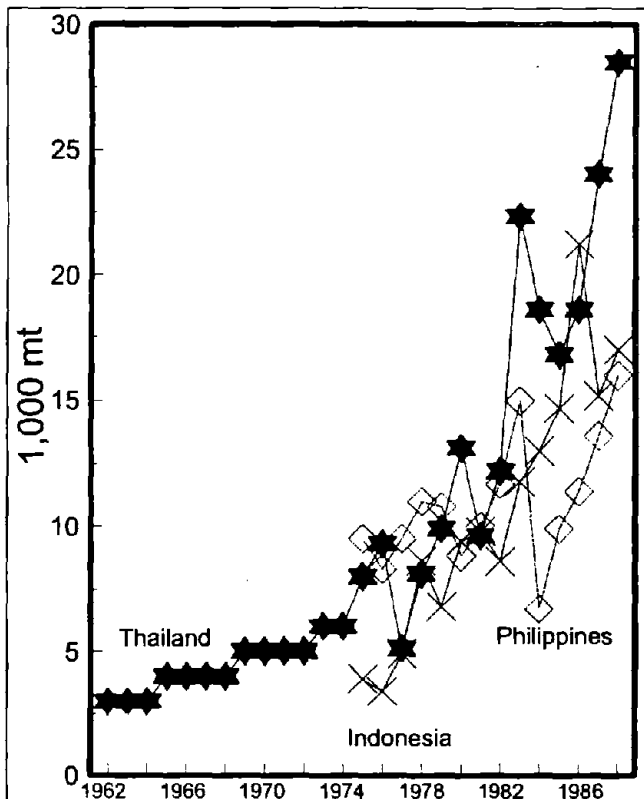


Figure 24.—Lead consumption—the ASEAN countries.

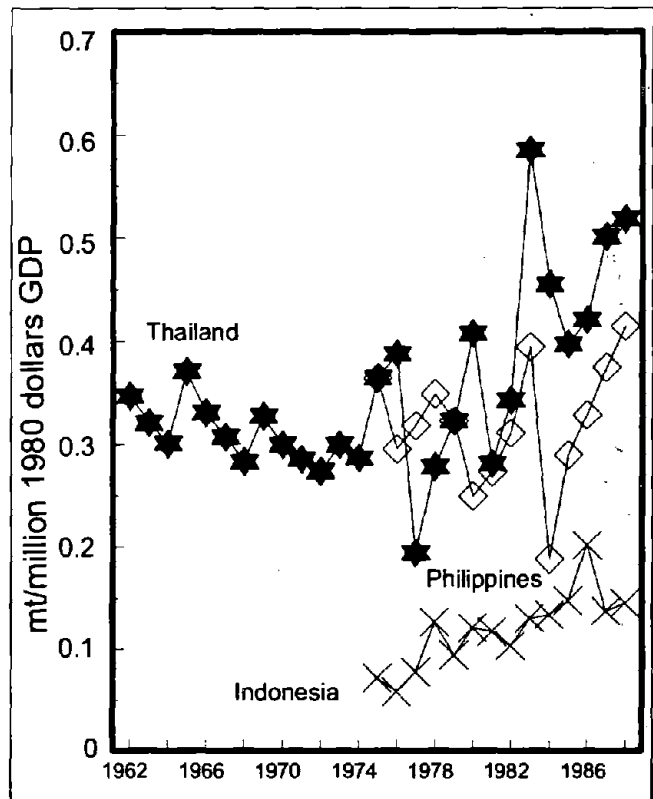


Figure 25.—Lead intensity of use—the ASEAN countries.

## LITERATURE REVIEW

Historically, two basic methodological approaches can be identified in the studies of minerals demand and economic development. One is the input-output (I/O) techniques and the other is econometric methods. The input-output analysis considers the interrelationships of all materials flows in the production processes of an economy by way of the interindustry transaction tables compiled on the national income and product account basis. By linking all input purchases of an industry from others to its output value, it lends itself to the analysis of intermaterial rivalry and produces internally consistent results.

As elaborate and comprehensive as it appears, the I/O model has some practical and theoretical problems. For it to be meaningful in minerals demand analysis, the mineral sectors in the model would have to be broken down to the four-digit level of the Standard Industrial Classification (SIC), which is a formidable task not easy to accomplish. (The latest SIC four-digit I/O tables available for the U.S. economy are for 1977.) Because the transaction tables are not available for future years, changes in the technical coefficients as well as the final demand would have to be assumed, which could prove controversial and could be as difficult as the task of forecasting the output vector itself.

In the econometric approach, the functional relationships between the demand for minerals and other economic variables are developed based on economic theory and common sense and estimated in the form of mathematical equations, using empirically observed data. As consumption and other relevant economic data have become available for more minerals and countries over the past 10 to 20 years, data are not as much of a problem for econometric modeling as for I/O analysis, but as will be discussed, econometric models are not without their share of flaws.

Following the tradition of energy studies conducted almost two decades earlier, many mineral demand studies in the 1970's focused on the concept of mineral intensity of use (MIU) and analyzed its relationships with economic development. Malenbaum (1978), for one, estimated a simple regression model with data for 1950-75 to relate physical units of minerals consumed per unit of real GDP to real per capita GDP, and used the estimated equations to project consumption trends of 12 nonfuel minerals in 10 world regions up to the year 2000. His analyses indicate that there exists a good correlation between a country's MIU and the level of economic development. In general, the measures of MIU rise rapidly with rising per capita income, but at some level of per capita income, they tend to peak out and decline thereafter. He ascribed such a relationship to the ongoing efforts to conserve materials and the expansion of the less mineral-intensive sectors, such as services in the economies.

Earlier, the Organization for Economic Cooperation and Development (OECD) in a steel consumption study (1974) also used a simple model to forecast a country's steel use intensity based on per capita GDP. The working hypothesis is very similar to Malenbaum's—that is, in the course of economic development, a country's steel use intensity rises slowly relative to economic growth in the early stage, rises more rapidly in the midstage as the construction sector and heavy industry expand, but tapers off in the later stage as engineering products tend to become lighter. Although the study recognized that economic structure as well as steel use patterns in the same steel-using sectors may also differ among the countries at the same level of per capita GDP, no efforts were made to take account of those factors. In the same vein, Roberts (1977) also came up with an S-shaped curve fitting in the study on the relationship between lead use intensity and per capita GDP, using cross-country data.

These studies, which have ended up with relating mineral intensity of use and per capita GDP in an inverted U form, have come to be known as the mineral use intensity hypothesis.

A steel consumption study conducted by the International Center for Industrial Studies for the United Nations (1978) also started with this hypothesis. However, it has found little correlation between steel use intensity and per capita GDP in developing countries and has recognized the need to relate steel use intensity to fixed capital formation and the activity levels of sectors that use steel such as shipbuilding, car making, and construction. The Bureau of Mines minerals demand forecasting system, as described in Information Circular 8825, is largely based on such end-use methods.

The use intensity hypothesis and the use intensity maturity theory it implies are, of course, not without suspects. Vogely (1976, 1977), for example, has questioned Malenbaum's finding, arguing that Government spending on education, defense, and research and development, which have spawned a portion of the U.S. services sector, is not necessarily materials conserving. He thinks the effects of material substitution and technological change on minerals demand, which are not explicitly considered in the use intensity hypothesis, are important factors to be considered in the metal-by-metal analysis of use intensity. In a study to examine whether the U.S. consumption of materials has increased or decreased as its economy advances over time, Vogely hypothesized two models and estimated them with the aggregate data for 1900-69 used in another study. In the first model, the consumption of materials, as expressed in a constant dollar value, is related linearly to the material price, the constant dollar GNP, and technology as represented by a time trend. The second model expresses the ratio of materials consumed to GDP as a linear function of material price and technology also represented by a time

trend. The estimation results indicate that the explanatory variables have adequately explained the variations in the dependent variables. However, a high degree of multicollinearity among the explanatory variables also makes it impossible to determine which ones are causing the impact.

Finally, in a study conducted for the Bureau of Mines by Radcliffe et al. (1981), the variations in the patterns of materials consumption in the industrialized countries were analyzed. Sixteen materials are covered under four primary categories: metals, ceramics, chemicals, and natural polymers. The analytical tools developed for forecasting materials consumption, however, consider all materials in an aggregate measure of per capita constant dollar value consumption, which is then related to per capita value added (also in constant dollars) in the construction and manufacturing sectors of the economy. The relationships are estimated in a linear and a double-log regression, respectively. The models differ from the others reviewed earlier in that instead of using strictly time-series data or cross-section data, a pooling of cross-section and time-series data derived from the input-output tables of four countries for the given years was used. The estimated models were then used to make projections for 1960-73 for the four sampled countries (the United States, the United Kingdom, West Germany, and Japan), as well as for others based on the time-series data of the independent variable, the per capita value added from manufacturing and construction, which the authors compiled from sources other than the input-output tables. The technique was intended to improve on the existing demand forecasting methodologies. But in a test of the models, the authors compared the projected per capita material consumption with the "actual" derived from the input-output tables of Italy and France for 1965 and found that the models overestimated by over 30%.

## FRAMEWORK FOR MODELING

The demand for a mineral being derived from the production of goods containing the mineral is obviously directly determined by the level of such production activity. The same level of manufacturing activity, however, may not consume the same amounts of minerals. Thus the concept of mineral intensity of use, which is generally defined as physical units of the mineral consumed per million dollars GDP (in constant prices) produced, presents itself as another direct determinant of mineral demand.

Questions, however, have been raised about the utility of the use intensity analysis. The most frequently mentioned is that the measure of MIU itself bears no relationship with the amounts of minerals that are embodied in traded goods

since what the numerator of the MIU measures is the apparent consumption of minerals, defined as domestic production and imports minus exports of the minerals in question. In other words, the apparent consumption concept takes no account of those minerals contained in either imported or exported goods and, therefore, does not really measure the actual amounts of minerals consumed. This measurement problem had been blamed for poor study results (Radcliffe et al., 1981, p. 175).

From the perspective of economic development study, what are most relevant are the flows of materials that have passed through the production processes to make what is known as the economy's GDP. The materials embodied in the imported capital goods do contribute to the making of the GDP but not on their own as individual materials. Their contributions to economic growth can be measured meaningfully only in the context of the machinery and equipment that contain them. This is so because it is of little interest or meaning to relate individual materials contained in a country's pool of capital stocks to its economic growth. Only the relationships between capital formation and growth make economic sense. Minerals embodied in imported consumer goods, on the other hand, have no direct bearing to domestic production. They probably are more meaningful as a measure of living standards. Minerals embodied in exported goods are implicitly included in the apparent consumption concept and, therefore, need not be a concern. The only things that may play havoc with the use intensity measure are the inventory changes, which are ignored in the definition of use intensity. Presumably, inventory changes are small and negligible. Therefore, for this study, the conventional measure of MIU will be used without redefining it.

By definition, MIU is the sum of the products of the ratio of the mineral consumed by an industry to the value of its total output and the ratio of the value of its total output to the total output values of all industries in the economy, or the GDP. In mathematical notation, it can be expressed as  $MIU(i) = \sum X(i,j)/Y = \sum (X(i,j)/(Q(j)) * (Q(j)/Y)$ , where  $X(i,j)$  is the amount of mineral  $i$  consumed by the  $j$ th industry,  $Q(j)$  its output, and  $Y = \sum Q(j)$ . The first components of the products on the right-hand side of the identity equation are known as the material composition of products, and the second are known as the product composition of income (Tilton, 1986).

Basically, two categories of factors may cause a direct change in the material composition of products. First, the amounts of minerals used to produce a unit of product may change as a result of technological changes and changes in product design prompted by regulatory requirements or consumer preference. For instance, the earlier hot dipping process greatly reduced the amount of tin required in can manufacturing and later the electrolytic processes had the

same effect in tinplate applications. Another example is the downsizing of automobiles, which necessarily leads to a reduced steel consumption by the auto industry. Second, the per unit requirement of minerals may also change because of substitution.

Substitution occurs for two reasons: Technological change is one, and economics is the other. A new material spawned by an emerging technology may substitute for minerals in some applications for the new materials' superior properties. Some obvious examples are plastics replacing steel in pipe manufacturing and substituting for aluminum in containers applications. Substitution also arises from producers' cost considerations. As the prices of the minerals in use rise and those of competing materials fall, the minerals in use tend to be replaced by their cheaper rivals, although such a relationship may not be easily modeled (Auty, 1985).

The processes that have led to changes in the material composition of products are not necessarily irreversible. For example, the trends toward a smaller car in the United States were for a while reversed somewhat as the public concerns for energy waned in the 1980's. The rapid changes in technology and consumer preference also mean that minerals may gain ground in one area of application but lose some in others at the same time. For example, copper is being replaced by optic fiber in telecommunication applications, but it is recovering some ground lost to aluminum and plastics in construction applications. Although the factors affecting changes in the material composition of products are relatively well known, the processes through which they effect those changes are so complex and fluid that it points to the difficulty and futility in attempting to estimate the effect of any single process on the material composition of products. From a modeling viewpoint, the most that can be done perhaps is to estimate the net effects of all of the processes that contribute to all of the changes.

Another direct cause for changes in MIU is the product composition of income, which in turn is affected by two sources of change. One is the intersectoral change, which refers to shifts in the relative importance of sectors in the economy as a higher level of industry is successively developed (for example, agriculture, manufacturing, services) in the course of economic development. The other is the intrasectoral change, which refers to differences in the mix of products and services produced in the individual sectors. For example, nondurable goods from light manufacturing industry tend to dominate the mix of manufactured goods earlier in the development, but as income rises, durable goods from heavy industry become more important.

To sum up, the factors affecting minerals demand are relatively well known. Minerals demand is directly affected by the aggregate level of economic activity and the MIU. The latter in turn is determined by technological

change, material substitution, and shifts in economic structure.

The mineral use intensity hypothesis focuses on the shifts in economic structure and contends that the effect of structural changes can be adequately captured by per capita GDP. The effects of technological change and material substitution are largely ignored. On the other hand, it is clear from the literature survey that although other econometric analysis of MIU has had decades of history, little headway has been made in terms of accounting for the effects of technological change, material substitution, and structural change in the economy. The models developed below are intended to close the gap.

## MODELS SPECIFICATION

Based on the preceding discussion, a mineral demand model is postulated as follows:

$$d = C1*y + C2'*X + C3'*y * X \quad (1)$$

where  $d$  = mineral demand in physical units,  $y$  = real GDP, and  $X$  = a vector of other explanatory variables. The  $C$ 's are model parameters to be estimated. The prime signs indicate a transposed vector. The last item, which describes the interactions between  $y$  and  $X$ , is added to account for a possible nonlinear relationship.

An MIU model is derived by dividing (1) through with  $y$ :

$$MIU = d/y = C1*1/y + C2'*(1/y)*X + C3'*X \quad (2)$$

The obvious choices for the elements in the vector of explanatory variables are technology ( $T$ ), the prices of the mineral and competing materials ( $P$ ), and a measure of structural change—both intersectoral and intrasectoral. Chenery and Syrquin (1975) identified 10 variables as indicators of structural change associated with economic growth. Of those 10, the 1 most relevant to minerals demand is industrial output as a percentage of GDP. Similarly, Roberts (1986) used GDP share of durable goods industry to measure changes in the product mix of GDP. Because data for the durable goods industry are not available for the countries under study, manufacturing production ( $M$ ) will be used as a proxy for intersectoral structural change. Durable goods production could be a good indicator for product mix change, but in the absence of the data, a pseudo-variable  $S$  will be developed and used to represent the intrasectoral change in the economy.

Formulas (1) and (2) thus can be written, respectively, as;

$$d = C1*y + C2'*(T + P + M + S) + C3'*y*(T + P + M + S) \quad (1a)$$

$$d/y = C1 + C2'*(T + P + M + S)/y + C3'* (T + P + M + S). \quad (2a)$$

To estimate these models, two variables, T and S, are yet to be defined. A frequently used proxy for technology is a simple time trend. But its high degree of correlation with other explanatory variables such as GDP often obscures the real sources of causality. Other measures such as the Index of Total Factor Productivity (Roberts, 1986) and automotive fuel efficiency (Considine, 1991) also have been used as a technology proxy, but the utility of these measures in this study is uncertain. Fortunately, this unobservable data problem may not seem so hopeless to resolve if it is assumed that all countries in the region have equal access to technology. This assumption is not unreasonable in view of the economic integration that has been going on in the region in the past 20 years. Furthermore, as Tilton (1986, 249) argued "... there is no reason to assume the developing world will eschew the more efficient and modern production technologies now available in favor of the obsolete and more material intensive techniques used years ago by the developed countries as they industrialized."

For the sake of simplicity, it is also assumed that mineral prices are about the same across the region. Although each country has a different tariff structure, and thus actual prices for consumers may vary, it is very difficult to determine the extent of the tariff variations and its effects on prices. Presumably it is small and negligible. Furthermore, many mineral supplies are secured by long-term contracts, and the contract prices may vary from the price series adopted for modeling purposes. For this reason, the accuracy of price information is always a problem. It is hoped that the assumption of a uniform price will subtract from, not add to, this problem. In any case, this is a strong assumption, which, it is hoped, can be relaxed when reliable price data become available.

Even with these assumptions, Formulas (1a) and (2a) may not be estimated in their entirety because of multicollinearity problem. Empirically, formula (2a) thus will be reduced to:

$$d(j)/y(j) = a_0 + a_1 * M(j)/y(j) + a_2 * S(j) \quad (2b)$$

where the j's in the parentheses denote country, and the substitution effects from technological and price changes

are subsumed in the constant term "a0". The explanatory variables  $M(j)/y(j)$  and  $S(j)$  are meant to represent, respectively, the intersectoral and intrasectoral structural changes in the economy. Estimation of (2b) for a given year, using cross-country data, thus will yield an equation with the estimated constant term capturing the substitution effects arising from technological and price changes. Repeating the estimation procedure for the successive years then will produce a time series of the net substitution effects as observed in the shifts of the intercept of the estimated equations. The variable  $S(j)$ , however, would have to be constructed in order to carry out such regression estimates.

To construct  $S(j)$ , we assume that the structural change affecting specific mineral demand is a stepwise function of time. A dummy variable technique then can be used to assign a set of relative values for the sampled countries. The choice of the initial set is made easier by patterning after the error terms obtained from the regression of Formula (2b) without  $S(j)$  as an explanatory variable. The final choice is made in the second stage of regressions on the basis of best data fitting. A successive estimation of the cross-section model, Formula (2b), over a period of time, thus, produces not only a time series of the net substitution effects but also a time series of the mineral specific structural variable  $S(j)$ . These two time-series proxy variables then are used to estimate the demand models in the simplified form of Formula (1a):

$$d(t) = b_0 + b_1 * GDP(t) + b_2 * T(t) + b_3 * S(t) + b_4 * M(t)/GDP(t) \quad (1b)$$

where the t's denote a time period (1 year). This formulation has all the explanatory variables of (2b) except GDP is added to reflect income level, a demand side factor affecting mineral demand. For simplicity, the prices of competing minerals are not considered.

This concludes the models specification. The following section discusses the models estimation and results. Particularly of interest is the extent to which the estimated coefficients of the two proxy variables are statistically significant in the time-series models as a relatively high incidence of such statistical significance may be seen as an indicator validating the two-tier modeling approach.

## MODELS ESTIMATION AND RESULTS

### CROSS-SECTION MODELS

The data used in the statistical analysis come from various sources. The metals consumption data are from various issues of Metal Statistics. The GDP data by industrial

sectors are provided by the World Bank on a 1980 constant dollar basis. The minerals price data are from the Bureau of Mines' Nonferrous Metal Prices in the United States Through 1988. Because the data availability is not uniform across minerals and countries, the sample size may vary. For

aluminum and zinc, the cross-section model is estimated from 1971 to 1988 with Japan, the Republic of Korea, Taiwan, Thailand, the Philippines, Indonesia, Singapore, and Malaysia in the sample. For copper, the model is estimated for 1978-88, with the sample including the above-mentioned countries except Singapore. The lead model is estimated for 1975-88, covering the same countries as the copper model except Malaysia. Hong Kong is not included in the cross-section analyses because data for its manufacturing share of GDP are not available. It, however, is included later in the time-series estimations for some minerals.

The least squares estimates of the models for the aluminum, copper, lead, and zinc are presented in tables 21-24, respectively. In these tables, the second column, under the label "Constant," presents the estimated sizes of the intercept of the linear regressions, showing the net substitution effects. The third column shows the estimated coefficients

for the manufacturing share of GDP, or the effects of intersectoral structural change. The fourth column lists the estimated coefficients for the proxy variable  $S(j)$ , or the effects of intrasectoral structural change. The numerics in the parentheses following the estimated coefficients are the  $t$  statistics, indicating the statistical significance of those estimates. Other statistics for the estimates shown on the tables are  $R$  squares adjusted for degree of freedom, the standard errors of regression (SE), and the means of the dependent variables (MDV).

The statistical results shown in tables 21-24 generally have borne out the model specification. The data fittings as indicated by the high values of adjusted  $R$  squares are all very good, and the estimated coefficients are in most cases highly significant. These indicate that at a point in time, with the substitution effects neutralized, the variations in mineral intensity of use among the countries can be fully explained by the structural variables.

**Table 21.—Regression estimates of the aluminum model**

| Year | Constant     | Manu. Share/GDP | $S(j)$      | Adj. R Sqr. | SE    | MDV   |
|------|--------------|-----------------|-------------|-------------|-------|-------|
| 1971 | -0.33 (-2.3) | 0.0311 (3.9)    | 0.94 (7.2)  | 0.95        | 0.130 | 0.645 |
| 1972 | -0.31 (-1.2) | 0.0300 (2.2)    | 1.01 (4.3)  | 0.87        | 0.232 | 0.694 |
| 1973 | 0            | 0.0168 (4.1)    | 1.35 (4.0)  | 0.94        | 0.174 | 0.868 |
| 1974 | 0            | 0.0215 (3.9)    | 0.93 (2.9)  | 0.81        | 0.239 | 0.834 |
| 1975 | 0            | 0.0137 (4.7)    | 1.19 (10.0) | 0.96        | 0.123 | 0.746 |
| 1976 | 0            | 0.0179 (7.1)    | 1.36 (12.6) | 0.97        | 0.109 | 0.921 |
| 1977 | 0            | 0.0208 (4.4)    | 1.29 (6.3)  | 0.91        | 0.206 | 0.973 |
| 1978 | 0            | 0.0191 (2.8)    | 1.37 (5.3)  | 0.89        | 0.271 | 1.125 |
| 1979 | 0            | 0.0229 (2.2)    | 1.34 (3.3)  | 0.74        | 0.430 | 1.230 |
| 1980 | 0            | 0.0180 (2.4)    | 1.01 (3.8)  | 0.80        | 0.310 | 1.001 |
| 1981 | 0            | 0.0132 (3.9)    | 1.14 (9.4)  | 0.95        | 0.141 | 0.973 |
| 1982 | 0            | 0.0204 (2.4)    | 1.11 (3.6)  | 0.79        | 0.344 | 1.130 |
| 1983 | 0            | 0.0232 (2.7)    | 1.22 (3.9)  | 0.80        | 0.376 | 1.246 |
| 1984 | -0.62 (-2.7) | 0.0418 (3.7)    | 0.77 (4.5)  | 0.93        | 0.166 | 0.887 |
| 1985 | -1.33 (-3.1) | 0.0720 (4.2)    | 0.75 (2.9)  | 0.85        | 0.312 | 1.000 |
| 1986 | -1.30 (-5.6) | 0.0682 (7.8)    | 0.81 (5.4)  | 0.95        | 0.167 | 1.073 |
| 1987 | -1.26 (-3.7) | 0.0622 (5.1)    | 0.91 (4.4)  | 0.90        | 0.232 | 1.093 |
| 1988 | -1.40 (-4.0) | 0.0736 (5.9)    | 0.73 (3.8)  | 0.91        | 0.214 | 1.204 |

**Table 22.—Regression estimates of the copper model**

| Year | Constant | Manu. Share/GDP | $S(j)$      | Adj. R Sqr. | SE    | MDV   |
|------|----------|-----------------|-------------|-------------|-------|-------|
| 1978 | 0        | 0.0037 (2.5)    | 1.14 (18.8) | 0.99        | 0.068 | 0.583 |
| 1979 | 0        | 0.0061 (4.5)    | 1.10 (26.3) | 0.99        | 0.048 | 0.798 |
| 1980 | 0        | 0.0032 (1.4)    | 1.15 (14.1) | 0.98        | 0.108 | 0.667 |
| 1981 | 0        | 0.0039 (1.3)    | 1.25 (13.4) | 0.98        | 0.140 | 0.831 |
| 1982 | 0        | 0               | 1.16 (24.1) | 0.98        | 0.114 | 0.719 |
| 1983 | 0        | 0.0098 (4.4)    | 1.10 (15.4) | 0.99        | 0.095 | 0.890 |
| 1984 | 0        | 0.0125 (6.1)    | 1.07 (17.7) | 0.99        | 0.088 | 0.959 |
| 1985 | 0        | 0.0128 (2.2)    | 0.94 (5.0)  | 0.89        | 0.243 | 0.906 |
| 1986 | 0        | 0.0087 (5.1)    | 1.40 (23.1) | 0.99        | 0.167 | 1.073 |
| 1987 | 0        | 0.0108 (11.8)   | 1.21 (42.5) | 0.99        | 0.043 | 1.099 |
| 1988 | 0        | 0.0106 (7.9)    | 1.15 (27.7) | 0.99        | 0.063 | 1.101 |

Table 23.—Regression estimates of the lead model

| Year | Constant      | Manu. Share/GDP | S(j)        | Adj. R Sqr. | SE    | MDV   |
|------|---------------|-----------------|-------------|-------------|-------|-------|
| 1975 | 0             | 0.0126 (60.2)   | 0.10 (11.8) | 0.99        | 0.011 | 0.287 |
| 1976 | 0             | 0.0126 (42.7)   | 0.14 (10.6) | 0.98        | 0.017 | 0.302 |
| 1977 | -0.089 (-1.4) | 0.0159 (5.7)    | 0.11 (2.1)  | 0.94        | 0.040 | 0.305 |
| 1978 | -0.146 (-4.4) | 0.0210 (16.4)   | 0.08 (5.2)  | 0.98        | 0.024 | 0.377 |
| 1979 | -0.145 (-4.3) | 0.0193 (15.2)   | 0.05 (44)   | 0.98        | 0.022 | 0.352 |
| 1980 | -0.027 (-19)  | 0.0113 (131)    | 0.19 (198)  | 1.00        | 0.001 | 0.340 |
| 1981 | -0.085 (-1.8) | 0.0156 (8.3)    | 0.51 (13.1) | 0.99        | 0.031 | 0.427 |
| 1982 | -0.207 (-4.2) | 0.0222 (12.1)   | 0.14 (6.1)  | 0.97        | 0.034 | 0.380 |
| 1983 | -0.225 (-4.8) | 0.0249 (14.9)   | 0.27 (13.4) | 0.98        | 0.030 | 0.488 |
| 1984 | -0.337 (-3.2) | 0.0254 (7.2)    | 0.23 (5.3)  | 0.93        | 0.065 | 0.413 |
| 1985 | -0.422 (-7.6) | 0.0296 (15.8)   | 0.27 (12.8) | 0.98        | 0.033 | 0.452 |
| 1986 | -0.391 (-7.1) | 0.0298 (16.1)   | 0.20 (11.9) | 0.99        | 0.035 | 0.498 |
| 1987 | -0.559 (-7.4) | 0.0353 (14.4)   | 0.26 (11.5) | 0.98        | 0.047 | 0.555 |
| 1988 | -0.788 (-3.7) | 0.0425 (6.2)    | 0.26 (4.5)  | 0.91        | 0.121 | 0.547 |

Table 24.—Regression estimates of the zinc model

| Year | Constant      | Manu. Share/GDP | S(j)        | Adj. R Sqr. | SE    | MDV   |
|------|---------------|-----------------|-------------|-------------|-------|-------|
| 1971 | 0             | 0.0296 (38.9)   | 0.29 (24.1) | 0.99        | 0.045 | 0.713 |
| 1972 | 0.093 (2.5)   | 0.0301 (18.5)   | 0.28 (25.6) | 0.99        | 0.032 | 0.829 |
| 1973 | 0.215 (3.3)   | 0.0214 (7.9)    | 0.20 (10.5) | 0.95        | 0.055 | 0.743 |
| 1974 | -0.180 (-3.9) | 0.0371 (19.4)   | 0.37 (30.4) | 0.99        | 0.031 | 0.784 |
| 1975 | -0.180 (-2.9) | 0.0323 (12.6)   | 0.26 (17.1) | 0.98        | 0.037 | 0.643 |
| 1976 | 0             | 0.0272 (33.7)   | 0.23 (12.5) | 0.94        | 0.053 | 0.725 |
| 1977 | 0             | 0.0277 (38.1)   | 0.34 (16.7) | 0.95        | 0.048 | 0.793 |
| 1978 | 0             | 0.0313 (40.3)   | 0.31 (14.8) | 0.97        | 0.051 | 0.921 |
| 1979 | 0             | 0.0281 (23.7)   | 0.41 (11.8) | 0.91        | 0.077 | 0.916 |
| 1980 | 0             | 0.0260 (25.9)   | 0.39 (11.2) | 0.91        | 0.069 | 0.810 |
| 1981 | 0             | 0.0254 (18.0)   | 0.44 (8.8)  | 0.85        | 0.099 | 0.815 |
| 1982 | -0.122 (-1.7) | 0.0309 (12.2)   | 0.46 (19.6) | 0.98        | 0.040 | 0.860 |
| 1983 | -0.194 (-2.5) | 0.0354 (13.0)   | 0.43 (14.4) | 0.97        | 0.046 | 0.853 |
| 1984 | 0             | 0.0248 (25.6)   | 0.55 (11.2) | 0.96        | 0.074 | 0.736 |
| 1985 | 0             | 0.0244 (49.0)   | 0.45 (18.7) | 0.98        | 0.038 | 0.680 |
| 1986 | -0.120 (-1.0) | 0.0305 (7.4)    | 0.41 (8.6)  | 0.94        | 0.083 | 0.743 |
| 1987 | -0.250 (-3.2) | 0.0340 (12.7)   | 0.47 (15.7) | 0.98        | 0.053 | 0.750 |
| 1988 | 0             | 0.0256 (22.1)   | 0.43 (7.6)  | 0.90        | 0.097 | 0.808 |

### Net Substitution Effects on the Mineral Intensity of Use

The estimates of the constant terms of the cross-section models capture the net substitution effects arising from technological and price changes. Those estimates are shown separately in the second column of tables 21-24 and collectively graphed in figure 26.

No net substitution effects are found for copper for 1978-88. For aluminum, the estimated substitution effects are slightly negative for 1971-72 and 0 for 1973-83. But as shown on figure 26, a drastic substitution of aluminum seems to have occurred in 1984-85, reducing the average use intensity by about 1.3 metric tons per million dollars of GDP (1980 prices) annually in 1985-88.

The net substitution effects for zinc appear relatively moderate. In 1972-73, the net substitution effects for zinc are estimated to be slightly positive, but for the rest of the sample period the estimates appear to have zigzagged in the narrow band between 0 and -0.25.

The estimates of substitution effects for lead are available only for the period 1975-88. The estimates are 0 for the first 2 years and negative for the rest of the period. They show a clear downward trend since 1977, with the declines accelerating in 1986-88. Thus, in 1978, the net substitution effects are estimated to have caused the average lead intensity to decrease by 0.15 mt per million dollars of GDP (1980 prices). This number in 1988 had increased to 0.79, a growth of more than five-fold in 10 years, reflecting a somewhat accelerated trend of other materials being substituted for lead.

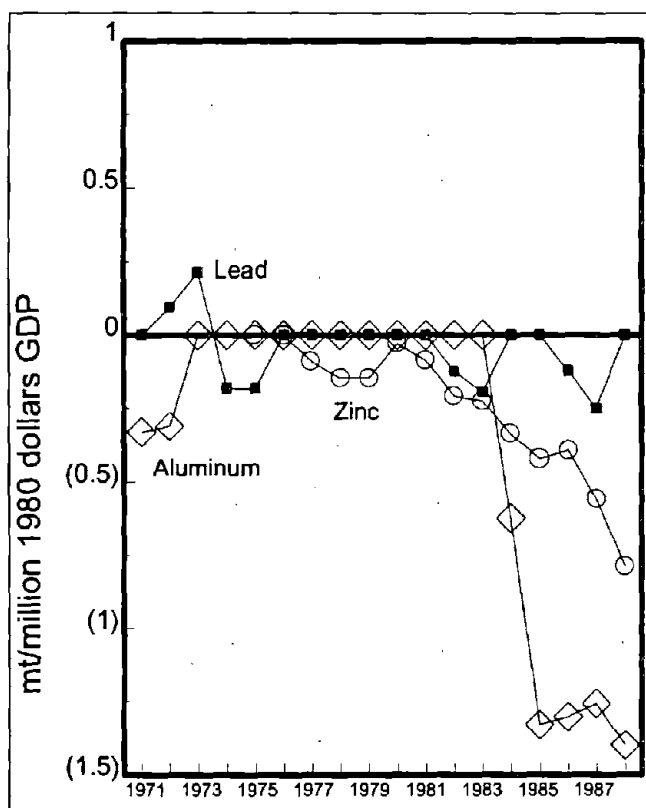


Figure 26.—Net substitution effects on the mineral intensity of use in the Asian Pacific Rim countries.

### Effects of Intersectoral Structural Change on the Mineral Intensity of Use

The intersectoral structural change as measured by the manufacturing share of GDP shows that the manufacturing sector has been expanding across all countries during the sample period of 1971-88. The average manufacturing share of GDP was just over 20% in 1971 but had increased to 29% in 1988. The estimated coefficients for this variable in tables 21-24 measure the marginal contribution of the intersectoral change in the economic structure to the MIU. Because the coefficients are all positive, the MIU is increasing over the years as a result of the intersectoral change in the economy. Intuitively, we expect the estimated coefficients to change very gradually from one year to the next or to hold at the same level for a period to show a pattern of a stepwise function. The patterns, however, may vary by minerals as reviewed below.

#### Aluminum

The estimated coefficients for the manufacturing share of GDP are about 0.03 for 1971-72 and fluctuate between 0.0132 and 0.0232 in 1973-83. Because the estimates are made independently, each can be considered an indepen-

dent random variable with a zero covariance. A statistical test then can be conducted to test the null hypothesis of equal population means. A series of such tests indicates that the null hypothesis cannot be rejected at all conventional statistical levels of significance for those estimated coefficients for 1973-83. It thus can be inferred that the average of the estimated coefficients of about 0.02 probably is good for this period. The estimated coefficient for 1984 is 0.0418, which is different from 0.02 in statistical significance. The estimates for 1985-88, however, are again very close, around 0.07.

Thus a 1% increase in the manufacturing share of GDP would have led to an increase in the aluminum use intensity of 0.03 (ton/million dollars of 1980 GDP) in 1971-72, 0.02 in 1973-83, and about 0.07 in 1984-88.

#### Copper

The estimates for the copper model are available only for 1978-88. As shown in table 22, the estimated coefficients for the manufacturing share of GDP are in general negligible for 1978-82. For 1983-88, the estimated coefficients again are very close, fluctuating around 0.01. The statistical tests again show that the null hypothesis of equal population means cannot be rejected.

#### Lead

As shown in table 23, the estimated coefficients for the manufacturing share of GDP rise gradually from 0.0126 in 1975 to 0.0425 in 1988. Except for a decline in 1979-80, the trend is up for the rest of the 1980's. Expansions in the manufacturing sectors of the Asian Pacific Rim countries continue to cause the lead use intensity to increase in the region.

#### Zinc

Again, the estimated coefficients for the manufacturing share of GDP as shown in table 24 fluctuate within a very narrow range in the sample period of 1971-88. During the 18-year span, the marginal impact of the manufacturing expansion to the zinc use intensity appears to have remained stable at around 0.03 ton per million of 1980 dollars of the GDP. The marginal impacts of the manufacturing share of GDP on the use intensity of the four minerals are also graphed in figure 27.

### Effects of the Intrasectoral Structural Change on the Mineral Intensity of Use

The estimated coefficients for the variable  $S(j)$  constructed to represent intrasectoral structural change are listed in tables 21-24 under the  $S(j)$  column. They are all highly statistically significant as indicated by the corresponding high values of the  $t$  statistics. The estimates of structural

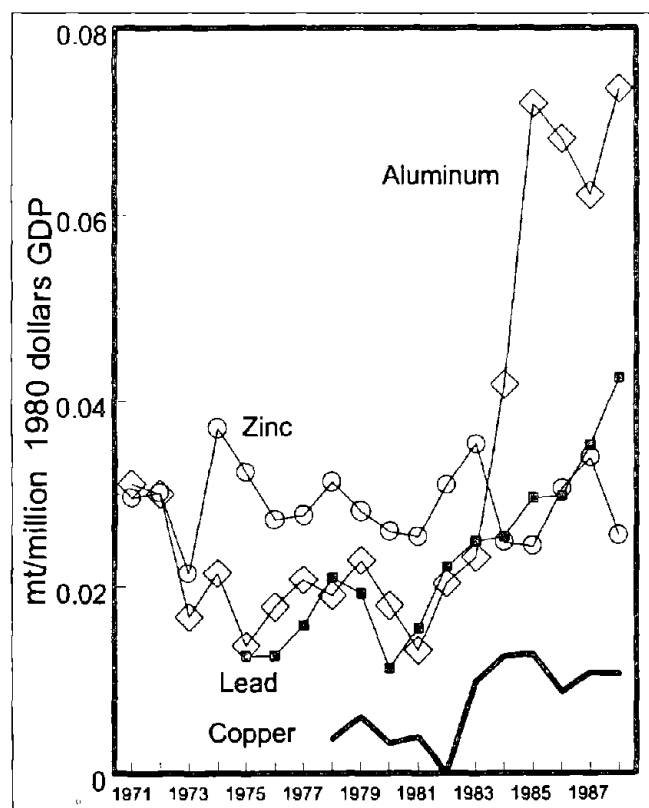


Figure 27.—Effects of intersectoral structural change on the mineral intensity of use in the Asian Pacific Rim countries.

impacts on the MIU are obtained by multiplying the estimated coefficients with the corresponding values of  $S(j)$ . Because all estimated coefficients are positive, a positive  $S(j)$  value would indicate a positive impact of structural change on the MIU. The values for  $S(j)$  are presented in tables 25-28. A commodity-by-commodity interpretation follows.

### Aluminum

The values of the structural variable  $S(j)$  for Japan are 1 for 1971-82 and 0.5 for 1983-88, meaning that economic structural changes had caused a positive impact on aluminum use intensity in Japan in 1971-82, but such an impact had been reduced by one-half after 1982. The values of this variable for the Republic of Korea are 0.5 for 1971-77 and 1 for 1978-88. Thus, contrary to the impact on Japan, the positive impact of structural change in the Republic of Korea on aluminum use intensity had doubled in 1978-88 from the previous level of 1971-77. Thailand and Malaysia appear to have followed the same patterns as the Republic of Korea but only on a belated time schedule. The values of the structural variable for Taiwan are 1 for the entire sample period, indicating that the positive impact of economic

structural change on aluminum use intensity had remained at the same level. The values of this variable are 0 for the Philippines and Singapore, suggesting that the economic structural change had not affected aluminum use intensity in the two countries. The same had been true for Indonesia until 1985, but beginning in 1986 the economic structural change in that country had started to have a positive impact on aluminum use intensity.

### Copper

The values of the structural variables for Japan indicate that the impact of economic structural change on copper use intensity had remained positive in 1978-88 but had

Table 25.—The values of the structural variable  $S(j)$  for aluminum

| Year | Japan | Korea | Taiwan | Thailand | Philippines | Indonesia | Singapore | Malaysia |
|------|-------|-------|--------|----------|-------------|-----------|-----------|----------|
| 1971 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1972 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1973 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1974 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1975 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1976 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1977 | 1.0   | 0.5   | 1.0    | 0.5      | 0           | 0         | 0         | 0        |
| 1978 | 1.0   | 1.0   | 1.0    | 0.5      | 0           | 0         | 0         | 0.5      |
| 1979 | 1.0   | 1.0   | 1.0    | 0.5      | 0           | 0         | 0         | 0.5      |
| 1980 | 1.0   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 0.5      |
| 1981 | 1.0   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 0.5      |
| 1982 | 1.0   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 0.5      |
| 1983 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 1.0      |
| 1984 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 1.0      |
| 1985 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0         | 0         | 1.0      |
| 1986 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0.5       | 0         | 1.0      |
| 1987 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0.5       | 0         | 1.0      |
| 1988 | 0.5   | 1.0   | 1.0    | 1.0      | 0           | 0.5       | 0         | 1.0      |

Table 26.—The values of the structural variable  $S(j)$  for copper

| Year | Japan | Korea | Taiwan | Thailand | Philippines | Indonesia | Malaysia |
|------|-------|-------|--------|----------|-------------|-----------|----------|
| 1978 | 1.0   | 1.0   | 1.0    | 0        | 0           | 0         | 0        |
| 1979 | 1.0   | 1.0   | 1.5    | 0        | 0           | 0         | 0        |
| 1980 | 1.0   | 1.0   | 1.5    | 0        | 0           | 0         | 0        |
| 1981 | 1.0   | 1.5   | 1.5    | 0        | 0           | 0         | 0        |
| 1982 | 1.0   | 1.5   | 1.5    | 0        | 0           | 0.25      | 0        |
| 1983 | 0.75  | 1.5   | 1.5    | 0        | 0           | 0         | 0.25     |
| 1984 | 0.75  | 1.5   | 1.5    | 0        | 0           | 0         | 0.25     |
| 1985 | 0.75  | 1.5   | 1.5    | 0        | 0           | 0         | 0.25     |
| 1986 | 0.5   | 1.5   | 1.5    | 0.25     | 0           | 0         | 0        |
| 1987 | 0.5   | 1.5   | 2      | 0.25     | 0           | 0         | 0.25     |
| 1988 | 0.5   | 1.5   | 2      | 0.25     | 0           | 0         | 0.5      |

**Table 27.—The values of the structural variable S(j) for zinc**

| Year | Japan | Korea | Taiwan | Thailand | Philippines | Indonesia | Singapore | Malaysia |
|------|-------|-------|--------|----------|-------------|-----------|-----------|----------|
| 1971 | 0.25  | 0     | 0.5    | 2.0      | 0           | 0         | 2.5       | -2.0     |
| 1972 | 0.25  | 0     | 0.5    | 2.5      | -0.75       | 0         | 1.5       | -1.0     |
| 1973 | 0.5   | 0     | 0.5    | 2.5      | -1          | 0         | 0.5       | -1.0     |
| 1974 | 0     | 0     | 0      | 1.5      | -0.5        | 0.5       | 2.5       | -1.0     |
| 1975 | 0     | 0.5   | 0.5    | 1.5      | -1.0        | 1.0       | 2.0       | -1.0     |
| 1976 | 0     | 0.5   | 0      | 1.5      | -0.5        | 1.0       | 2.0       | -1.0     |
| 1977 | 0     | 0.5   | 0      | 1.5      | 0           | 1.0       | 1.25      | -1.0     |
| 1978 | -0.25 | 0.5   | 1.0    | 1.5      | 0           | 1.0       | 1.25      | -1.0     |
| 1979 | 0     | 1.0   | 0      | 1.5      | 0           | 1.0       | 1.75      | -0.5     |
| 1980 | 0     | 1.0   | 0      | 1.0      | -0.5        | 1.0       | 1.0       | -0.5     |
| 1981 | -0.5  | 1.0   | 0      | 1.0      | 0           | 1.0       | 1.0       | -0.5     |
| 1982 | -0.5  | 1.0   | 0      | 1.0      | 0           | 1.0       | 1.5       | -0.5     |
| 1983 | -0.5  | 1.0   | 0      | 1.0      | 0           | 1.0       | 0.5       | -0.5     |
| 1984 | -0.5  | 1.0   | 0      | 1.0      | 0           | 0         | -0.25     | -0.25    |
| 1985 | -0.5  | 1.0   | 0      | 1.0      | -0.5        | 0         | -0.25     | -0.25    |
| 1986 | -0.5  | 1.0   | 0      | 1.0      | -0.5        | 0         | -0.25     | -0.25    |
| 1987 | -1.0  | 1.0   | 0      | 1.0      | 0           | 0         | -0.25     | -0.25    |
| 1988 | -1.0  | 1.0   | 0      | 1.0      | 0           | 0         | 0         | 0        |

**Table 28.—The values of the structural variable S(j) for lead**

| Year | Japan | Korea | Taiwan | Thailand | Philippines | Indonesia |
|------|-------|-------|--------|----------|-------------|-----------|
| 1975 | 0     | -0.5  | 0      | 1.0      | 0.5         | -0.5      |
| 1976 | 0     | -0.5  | 0.5    | 1.0      | 0           | -0.5      |
| 1977 | 0     | 0     | 1.0    | 0        | 0           | 0         |
| 1978 | -1.0  | 0     | 1.0    | 0        | 0           | 0.5       |
| 1979 | -1.0  | 1.5   | 0      | 0.5      | 0           | 0.5       |
| 1980 | 0     | 1.0   | 0      | 1.0      | 0           | 0         |
| 1981 | 0     | 1.0   | 0.25   | 0        | 0           | 0         |
| 1982 | -1.0  | 1.0   | 0      | 0.5      | 0           | 0         |
| 1983 | -1.0  | 0.5   | 0.5    | 1.0      | 0           | 0         |
| 1984 | -1.0  | 0.5   | 0.5    | 1.0      | 0           | 0         |
| 1985 | -1.0  | 1.0   | 0      | 1.0      | 0           | 0         |
| 1986 | -1.5  | 1.0   | 0.5    | 1.0      | 0           | 0         |
| 1987 | -1.5  | 0.5   | 1.0    | 1.0      | 0.5         | 0         |
| 1988 | -1.5  | 0.5   | 1.0    | 1.0      | 0.5         | 0         |

decreased in two steps separately in 1983 and 1986. Again, contrary to the impact on Japan, the impacts of economic structural change on copper use intensity in the Republic of Korea and Taiwan had been on the rise. They were 1½ times larger in 1988 than in 1978 in the Republic of Korea, and in Taiwan, the impacts had grown twice as large in the sample period. In the ASEAN Four, only Malaysia and Thailand had started to show the positive effect of structural change on copper use intensity—the former starting in 1983 and the latter in 1986.

## Lead

The values of the structural variable for Japan are mostly 0 in 1975-81 but turn negative in 1982-88, suggesting that the economic structural change had a negative impact on lead use intensity in Japan beginning in 1982. Furthermore, the negative impact had intensified in 1986. Again, in contrast, economic structural change had produced a positive influence on lead use intensity in the Republic of Korea and Taiwan, although the trends are not as clear as for copper and aluminum. Economic structural change also caused a positive impact on lead use intensity in Thailand but little in the Philippines and Indonesia, although a positive impact trend may be developing in the Philippines.

## Zinc

The values of the structural variable indicate that economic structural change had a positive impact on Japan's zinc use intensity in 1971-73. The impact, however, had disappeared in 1974-80 and turned negative in 1981. The values for the Republic of Korea, on the other hand, show that economic structural change had a positive impact on zinc use intensity beginning in 1975, with the impact doubling in magnitude in 1987-88. The values of this variable for Taiwan were 0.5 in the early 1970's but have been 0 since 1979. For Thailand, the values of the structural variable had peaked at 2.5 in 1972-73 and dropped to 1.5 in 1974-78 and to 1 in 1979. Thus, economic structural change had continued to exert a positive impact on Thailand's zinc use intensity, but such an impact had been diminishing. A similar situation is also found for Singapore, except that the impact there had turned negative in 1984-87. The values of the structural variable for Malaysia were -2 in 1971, but after that they increased consistently in several steps and became 0 in 1988. The values of the structural variable for the Philippines fluctuated between -1 and 0 during the sample period of 1971-88 without establishing a clear trend. The values of the structural variable for Indonesia are 1 for 1975-83 but 0 since 1984, indicating that economic structural change had ceased to contribute positively to zinc use intensity since 1984.

As noted earlier, the values of this structural variable are developed independently for each year. Yet over the years, they in general exhibit a continuity in the form of a stepwise function. The long-term trends are that the values tend to increase in the earlier periods of economic development, peak somewhere in the middle, and decrease afterward in the later stage. These trends are in line with the changing patterns of the mix of manufactured goods observed in the industrialized countries. In those countries, the mix of manufactured goods is first dominated by nondurable goods and then by durable goods; later on, the lighter products of

the high-tech industry also become important, supplanting the latter. The implications of this variable will be discussed further later.

### TIME-SERIES (DEMAND) MODELS

This subsection presents the regression estimates of the minerals demand models in the form of Formula (1b) as developed in the previous section. Estimations are made for each of the four minerals and for the countries for which mineral consumption data are available. The estimated models can be used to forecast minerals demand in those countries, but instead of providing forecasts, our main purpose here is to examine the statistical significance of the constant terms and economic structural variables of the cross-section models as developed in the previous subsection.

The constant terms of the cross-section models are supposed to have captured the net substitution effects due to technological and price changes. The estimates of the constant terms as presented in the second column of tables 21-24 thus are used as the proxy to technology and prices in the time-series mineral demand models. In effect, this variable represents the factors affecting the material mix of

products. The other explanatory variables are the manufacturing share of GDP (M/GDP), representing the intersectoral change, and the variable S, representing the intrasectoral change in the structure of the economy.

The statistical significance of the estimated coefficients of these variables will in a way validate the two-tier modeling approach that we have adopted as a way to overcome the unobserved data problems. Also included as an explanatory variable is a dummy variable (EDMY) deployed to make adjustments for the years in which the normal relationships between mineral demand and the explanatory variables are disrupted by unusual events such as recession. Because the Asian Pacific Rim economies are well geared to exporting to Western industrialized countries, their economic activities respond to the economic cycles of the Western countries with a time lag. Mineral consumption thus tends to be considerably lower at the peaks and higher at the valleys of the economic cycles. The use of the dummy is justified to the extent that it smooths out these irregularities and brings out an estimated relationship that is closer to the theoretical expectations.

The regressions with an estimated coefficient for AR(1) or AR(2) are corrected for the first- or second-order serial

Table 29.—Regression estimates of the aluminum demand models

| Country           | Explanatory Variables |                  |                 |                |               |                 |                   |            |        |       |        |
|-------------------|-----------------------|------------------|-----------------|----------------|---------------|-----------------|-------------------|------------|--------|-------|--------|
|                   | Const.                | GDP              | Tech            | S(j)           | M/GDP         | EDMY            | AR(1)             | Adj. R Sq. | DW     | SE    | MDV    |
| Japan             | —                     | 0.013<br>(44.2)  | 122.7<br>(5.4)  | 275.1<br>(9.5) | —             | 181.8<br>(13.1) | -0.7882<br>(-3.2) | 0.9156     | 2.4037 | 47.08 | 1592.5 |
| Republic of Korea | -54.76<br>(-10.5)     | 0.0022<br>(31.5) | —               | —              | —             | 24.02<br>(4.8)  | —                 | 0.9860     | 1.8622 | 8.29  | 99.81  |
| Taiwan            | -97.3<br>(-2.8)       | 0.0022<br>(13.3) | —               | —              | 2.89<br>(2.4) | 25.64<br>(8.2)  | —                 | 0.9864     | 2.7119 | 6.21  | 93.68  |
| Thailand          | -32.28<br>(-21.5)     | 0.0021<br>(21.9) | 20.52<br>(19.4) | 13.74<br>(4.4) | —             | 4.30<br>(3.4)   | —                 | 0.9848     | 2.6041 | 2.26  | 40.1   |
| Philippines       | 8.98<br>(3.8)         | 0.0002<br>(2.7)  | 6.7694<br>(8.0) | —              | —             | 4.57<br>(9.1)   | —                 | 0.9041     | 1.7977 | 1.8   | 13.41  |
| Singapore         | -3.29<br>(-2.3)       | 0.0006<br>(6.9)  | —               | —              | —             | 3.36<br>(9.1)   | —                 | 0.9437     | 1.9505 | 0.88  | 6.3    |
| Malaysia          | -10.86<br>(-3.3)      | 0.0011<br>(5.5)  | 3.46<br>(2.9)   | 8.18<br>(2.2)  | —             | 4.88<br>(7.8)   | —                 | 0.9737     | 2.0672 | 1.9   | 18.2   |
| Indonesia         | —                     | 0.0004<br>(3.7)  | —               | 17.2<br>(1.8)  | —             | 5.04<br>(4.7)   | 0.8734<br>(7.0)   | 0.9649     | 1.9508 | 4.2   | 26.03  |
| Hong Kong         | 6.98<br>(8.5)         | 0.0006<br>(19.0) | 3.33<br>(5.2)   | —              | —             | 13.9<br>(10.2)  | 0.6752<br>(3.1)   | 0.9456     | 1.5166 | 1.45  | 23.45  |

correlation of the disturbance terms. The results of the regressions of the four mineral demand models are presented in tables 29-32. As can be seen from these tables, the data fittings are very good, with the adjusted R squares over 90% for every mineral model but one. The estimated coefficients for all of the explanatory variables are in most cases statistically highly significant except for the M/GDP. This variable fails to enter virtually all of the estimated

equations with any statistical significance probably because of its high correlation with the GDP, another important explanatory variable. As discussed earlier, the impact of the intersectoral change on mineral demand is positive and either flat or on the rise. The effect of this variable, therefore, should be reflected in either the constant term or the GDP. Details of the individual estimates are discussed below.

**Table 30.—Regression estimates of the copper demand models**

| Country           | Explanatory Variables |                  |                |                |                  |                  |           | DW     | SE     | MDV     |
|-------------------|-----------------------|------------------|----------------|----------------|------------------|------------------|-----------|--------|--------|---------|
|                   | Const.                | GDP              | S(j)           | EDMY           | AR(1)            | AR(2)            | Adj.R Sq. |        |        |         |
| Japan             |                       | 0.0008<br>(27.3) | 338.8<br>(7.2) | 153.3<br>(4.3) | 0.0961<br>(10.3) |                  | 0.7352    | 2.4226 | 33.08  | 1,263.5 |
| Republic of Korea | -159.0<br>(-8.4)      | 0.0027<br>(12.4) | 70.2<br>(3.6)  | —              |                  | -1.193<br>(-2.0) | 0.9658    | 2.6922 | 154.28 | 188.4   |
| Taiwan            | -119.81<br>(-10.3)    | 0.0032<br>(13.0) | 44.7<br>(3.6)  | —              | 38.5<br>(6.4)    | —                | 0.9885    | 1.9066 | 6.00   | 112.8   |
| Thailand          | -18.5<br>(-6.4)       | 0.0008<br>(9.5)  | 29.0<br>(5.1)  | 3.3<br>(4.7)   | —                | —                | 0.9909    | 2.1308 | 1.04   | 12.9    |
| Philippines       | -5.77<br>(-0.9)       | 0.0003<br>(1.7)  | —              | —              | 5.91<br>(9.7)    |                  | 0.9037    | 1.8018 | 1.16   | 6.3     |
| Malaysia          | -48.49<br>(-7.9)      | 0.0020<br>(9.2)  | 12.19<br>(2.4) | —              | 7.1<br>(5.0)     | —                | 0.9399    | 2.2749 | 2.76   | 10.7    |
| Indonesia         | -29.12<br>(-7.8)      | 0.0005<br>(12.1) | —              | 4.3<br>(5.5)   | —                | —                | 0.9539    | 2.2673 | 2.01   | 16.3    |

**Table 31.—Regression estimates of the lead demand models**

| Country           | Explanatory Variables |                  |                |               |               |                  |           | DW     | SE   | MDV    |
|-------------------|-----------------------|------------------|----------------|---------------|---------------|------------------|-----------|--------|------|--------|
|                   | Const.                | GDP              | Tech           | S(j)          | EDMY          | AR(2)            | Adj.R Sq. |        |      |        |
| Japan             | —                     | 0.0004<br>89.3   | 160.3<br>(7.7) | 35.5<br>(4.0) | 30.7<br>(7.3) | —                | 0.9415    | 2.0486 | 9.58 | 362.51 |
| Republic of Korea | -63.18<br>(-117)      | 0.0015<br>(23.1) | —              | —             | 22.6<br>(3.5) | —                | 0.9767    | 1.7967 | 6.16 | 55.45  |
| Taiwan            | -30.24<br>(-18.4)     | 0.0013<br>(36.7) | —              | 10.1<br>(4.7) | 4.2<br>(3.3)  | 0.4412<br>(-1.6) | 0.9913    | 1.7735 | 1.95 | 38.65  |
| Thailand          | -13.44<br>(-4.7)      | 0.0007<br>(6.5)  | 5.3<br>(1.8)   | 6.2<br>(7.6)  | 2.5<br>(3.6)  | —                | 0.9728    | 2.0809 | 1.12 | 14.47  |
| Philippines       | -2.01<br>(-0.9)       | 0.0004<br>(6.0)  | —              | 3.8<br>(3.4)  | 1.1<br>(7.3)  | —                | 0.8617    | 2.2265 | 0.86 | 10.66  |
| Indonesia         | -11.51<br>(-6.6)      | 0.0003<br>(10.1) | 3.97<br>(1.8)  | —             | 6.2<br>(8.1)  | —                | 0.9771    | 1.6982 | 0.77 | 10.52  |

Table 32.—Regression estimates of the zinc demand models

| Country           | Explanatory Variables |                   |                |                |                |                   |           |        |       |       |
|-------------------|-----------------------|-------------------|----------------|----------------|----------------|-------------------|-----------|--------|-------|-------|
|                   | Const.                | GDP               | Tech           | S(j)           | EDMY           | AR(1)             | Adj.R Sq. | DW     | SE    | MDV   |
| Japan             | 456.6<br>(12.8)       | 0.0003<br>(7.4)   | 196.9<br>(6.1) | 74.5<br>(3.5)  | 27.2<br>(13.7) | —                 | 0.9703    | 1.8197 | 10.84 | 725.4 |
| Republic of Korea | -35.70<br>(-3.6)      | 0.0016<br>(13.4)  | —              | —              | 15.8<br>(4.0)  | 0.57<br>(2.0)     | 0.9866    | 1.6072 | 5.99  | 81.8  |
| Taiwan            | —                     | 0.00102<br>(42.1) | —              | 5.2<br>(2.1)   | 10.0<br>(7.8)  | -0.3513<br>(-1.3) | 0.9746    | 1.7409 | 3.00  | 42.7  |
| Thailand          | -7.98<br>(-2.2)       | 0.0012<br>(21.7)  | 19.42<br>(4.4) | 2.7<br>(2.0)   | 4.2<br>(6.5)   | —                 | 0.9826    | 2.3346 | 1.60  | 33.7  |
| Philippines       | 7.71<br>(2.5)         | 0.0004<br>(4.6)   | —              | 5.8<br>(4.0)   | 6.0<br>(7.3)   | —                 | 0.9198    | 2.2744 | 1.56  | 18.2  |
| Singapore         | -4.40<br>(-1.6)       | 0.0009<br>(4.9)   | 8.26<br>(2.8)  | 4.3<br>(7.2)   | 1.9<br>(3.8)   | 0.4985<br>(2.3)   | 0.8592    | 1.9727 | 1.18  | 9.7   |
| Malaysia          | 10.51<br>(6.9)        | 0.0002<br>(5.9)   | —              | 5.87<br>(7.8)  | 2.5<br>(7.5)   | —                 | 0.9749    | 2.2003 | 0.71  | 11.8  |
| Indonesia         | —                     | 0.0005<br>(3.7)   | 29.11<br>(2.3) | 23.85<br>(3.3) | —              | 0.8989<br>(5.3)   | 0.9215    | 1.5050 | 4.93  | 42.9  |
| Hong Kong         | 3.83<br>(3.1)         | 0.0005<br>(11.9)  | —              | —              | —              | 8.3<br>(10.2)     | 0.9254    | 2.2420 | 1.95  | 18.9  |

### Real GDP

Predictably, real GDP is one of the most significant explanatory variables for minerals demand. All estimated coefficients point to increases in minerals consumption as a result of growth in real GDP. Based on the estimated coefficients, the elasticities of metal demand with respect to GDP growth are calculated at the mean values and presented in table 33.

Table 33.—Elasticities of metal demand with respect to real GDP

| Country           | Metals   |        |      |      |
|-------------------|----------|--------|------|------|
|                   | Aluminum | Copper | Lead | Zinc |
| Japan             | 0.85     | 0.42   | 1.09 | 0.46 |
| Republic of Korea | 1.50     | 1.06   | 1.85 | 1.42 |
| Taiwan            | 1.43     | 1.18   | 1.51 | 1.19 |
| Thailand          | 1.69     | 1.92   | 1.60 | 1.17 |
| Malaysia          | 1.47     | 4.45   | NA   | 0.69 |
| Philippines       | 0.47     | 1.50   | 1.12 | 0.67 |
| Indonesia         | 2.80     | 2.30   | 1.88 | 1.89 |
| Singapore         | 1.22     | NA     | NA   | 1.09 |
| Hong Kong         | 0.75     | NA     | NA   | 0.72 |

NA denotes not available.

In general, metal demands are inelastic in Japan, where the economic development has achieved maturity, and growth has slowed down relatively. Mineral demands are growing faster than GDP in Taiwan, the Republic of Korea, Thailand, Malaysia, and Indonesia, where the economies have been growing at a fast pace and are expected to continue to do well in the near future. The Philippines shows mixed patterns for minerals demand—elastic in copper and lead but inelastic in aluminum and zinc—which may suggest that the economy is still in an early stage of development. The demand elasticities for Singapore and Hong Kong, on the other hand, indicate that minerals have played a larger role in the economic development of the former than of the latter.

### Technology/Prices and Intrasectoral Structure S(j)

As discussed earlier, these two explanatory variables are developed from the cross-section models. The extent to which they are statistically significant in the estimated time-series models thus would provide a measure of empirical evidence to support the two-tier modeling approach. In the following, the relative frequencies of these two variables entering the estimated time-series models with the significance levels of alpha ( $\alpha$ ) no greater than 5% are tabulated

by mineral models in table 34, and by country models in table 35.

Of the aluminum and zinc models estimated for the nine countries, the technology/prices variable is significant in five of the former and four of the latter. It is also significant in one-half of the lead models. The intrasectoral structural variable  $S(j)$  is significant in four of the nine aluminum models and almost totally significant in the zinc models. It is also significant in five of the seven copper models and in two-thirds of the lead models.

The two proxy variables are statistically significant in all models of Japan and Thailand. The technology/prices variable is significant in two-thirds of the Indonesian models; in one-half of the models of Malaysia, Singapore, and Hong Kong; and in one-third of the models of the Philippines. The structural variable is also significant in all of the Malaysian models and three-quarters of the models of Taiwan and Indonesia. It is significant in one-half of the models of the Philippines and Singapore and in one-quarter of the models of the Republic of Korea.

Thus, when confronted with the empirical data, overall, our theoretical models have fared well. They appear to have the support of the majority of the statistical evidence.

**Table 34.—Relative frequencies of technology/price and intrasectoral structural variables significant at  $\alpha \leq 0.05$  by mineral models**

| Mineral models | Explanatory Variables |                         |
|----------------|-----------------------|-------------------------|
|                | Technology/Prices     | Intrasectoral structure |
| Aluminum       | 5/9                   | 4/9                     |
| Copper         | —                     | 5/7                     |
| Lead           | 3/6                   | 4/6                     |
| Zinc           | 4/9                   | 7/9                     |

**Table 35.—Relative frequencies of technology/price and intrasectoral structural variables significant at  $\alpha \leq 0.05$  by country models**

| Country models    | Explanatory Variables |                         |
|-------------------|-----------------------|-------------------------|
|                   | Technology/Prices     | Intrasectoral structure |
| Japan             | 3/3                   | 4/4                     |
| Thailand          | 3/3                   | 4/4                     |
| Indonesia         | 2/3                   | 3/4                     |
| Malaysia          | 1/2                   | 3/3                     |
| Philippines       | 1/3                   | 2/4                     |
| Singapore         | 1/2                   | 1/2                     |
| Hong Kong         | 1/2                   | 0/2                     |
| Republic of Korea | 0/3                   | 1/4                     |
| Taiwan            | 0/3                   | 3/4                     |

## MINERAL INTENSITY OF USE AND ECONOMIC DEVELOPMENT— THE MINERAL INTENSITY OF USE HYPOTHESIS REVISITED

Because the products of the estimated coefficients of the variable  $S(j)$ , and its values measure the part of the MIU attributable to intrasectoral changes in the economic structure, the values of this variable, in a sense, can be interpreted as the countries' propensity to consume minerals because of intrasectoral changes in the economic structure. As shown in tables 25-28, they generally tend to remain constant for a while and then move up or down in step, conforming to the expected patterns of structural changes in the economy. In particular, the values of  $S(j)$  for Japan show a declining trend for each of the four minerals, while those of the other countries show a rising trend or no trend at all.

On the basis of the mineral intensity of use hypothesis, the values of  $S(j)$  for all sampled countries are plotted on an inverted-U curve, with the horizontal axis representing the level of economic development. As to which side of the curve the value of  $S(j)$  should be assigned is decided by the trend of the variables. In the case for Japan, it is clear that all MIUs have been decreasing since the early 1970's, as discussed in the second section of this report. In the case when the variables show no clear trend, it is assumed that

the peak has not been reached, and the value is assigned on the left-hand side of the curve.

A set of three panels of the plotted graph are presented for each of the four minerals in figure 28. In each case, the three panels represent the first, the middle, and the last year of the sample periods. For example, the left three panels of figure 28 depict the propensities to consume aluminum because of intrasectoral structural change for the years 1971, 1978, and 1988.

As can be seen, in 1971, Japan and Taiwan with the  $S(j)$  value of 1 were on the top of the inverted-U curve, while the Republic of Korea and Thailand with the value of 0.5 were at the middle of the left-hand side of the curve—the Philippines, Indonesia, Singapore, and Malaysia—all had the value of 0. The second panel shows that, by 1978, the Republic of Korea had moved up to join Japan and Taiwan at the top of the curve, while Thailand and Malaysia also had moved up midway on the curve from the bottom. The Philippines, Indonesia, and Singapore remained unchanged at the bottom. The last panel shows that by 1988, Thailand and Malaysia had moved up to join Taiwan and the Republic of Korea at the top of the curve, while Japan had moved

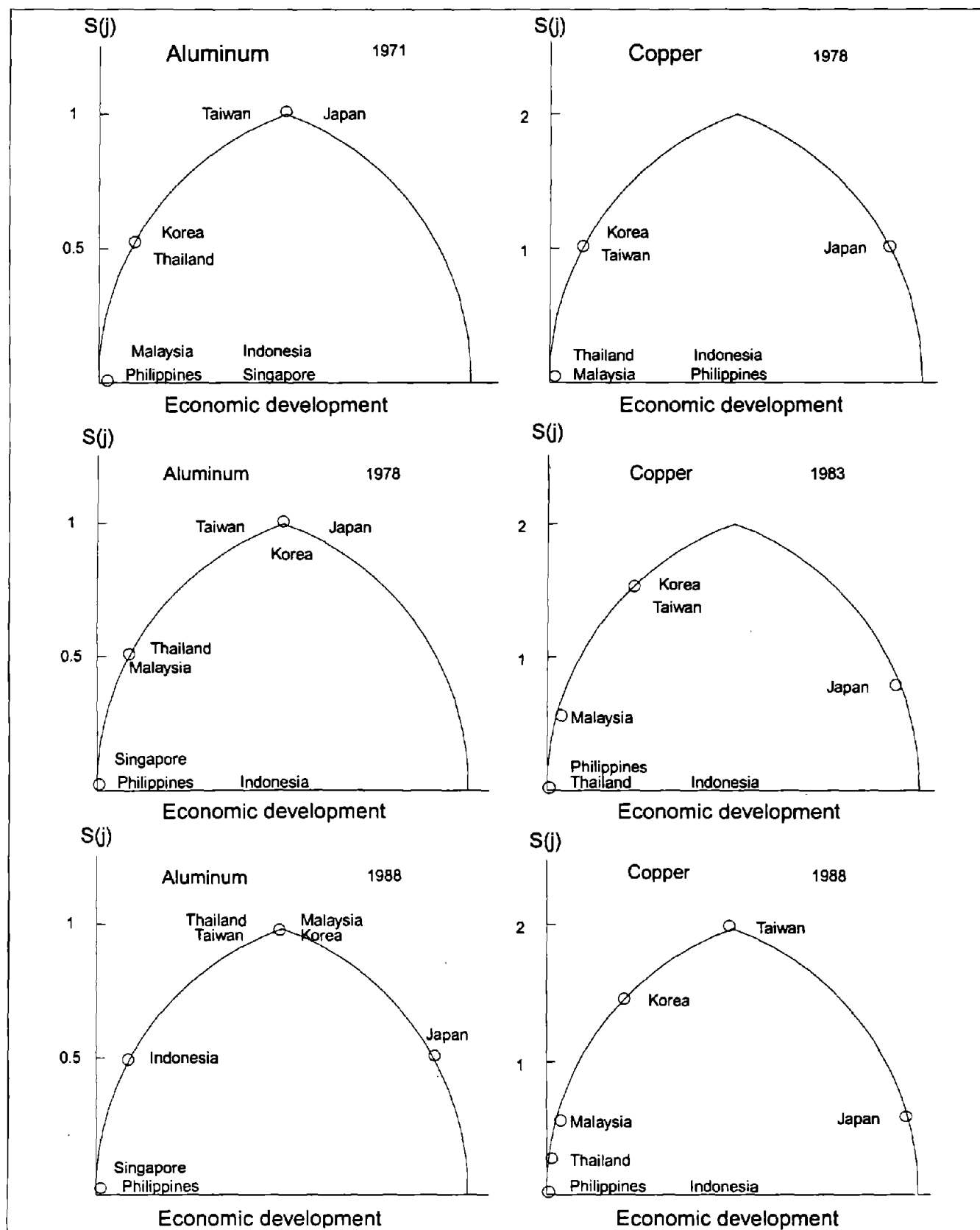


Figure 28.—Propensities to consume minerals because of intrasectoral structural changes.

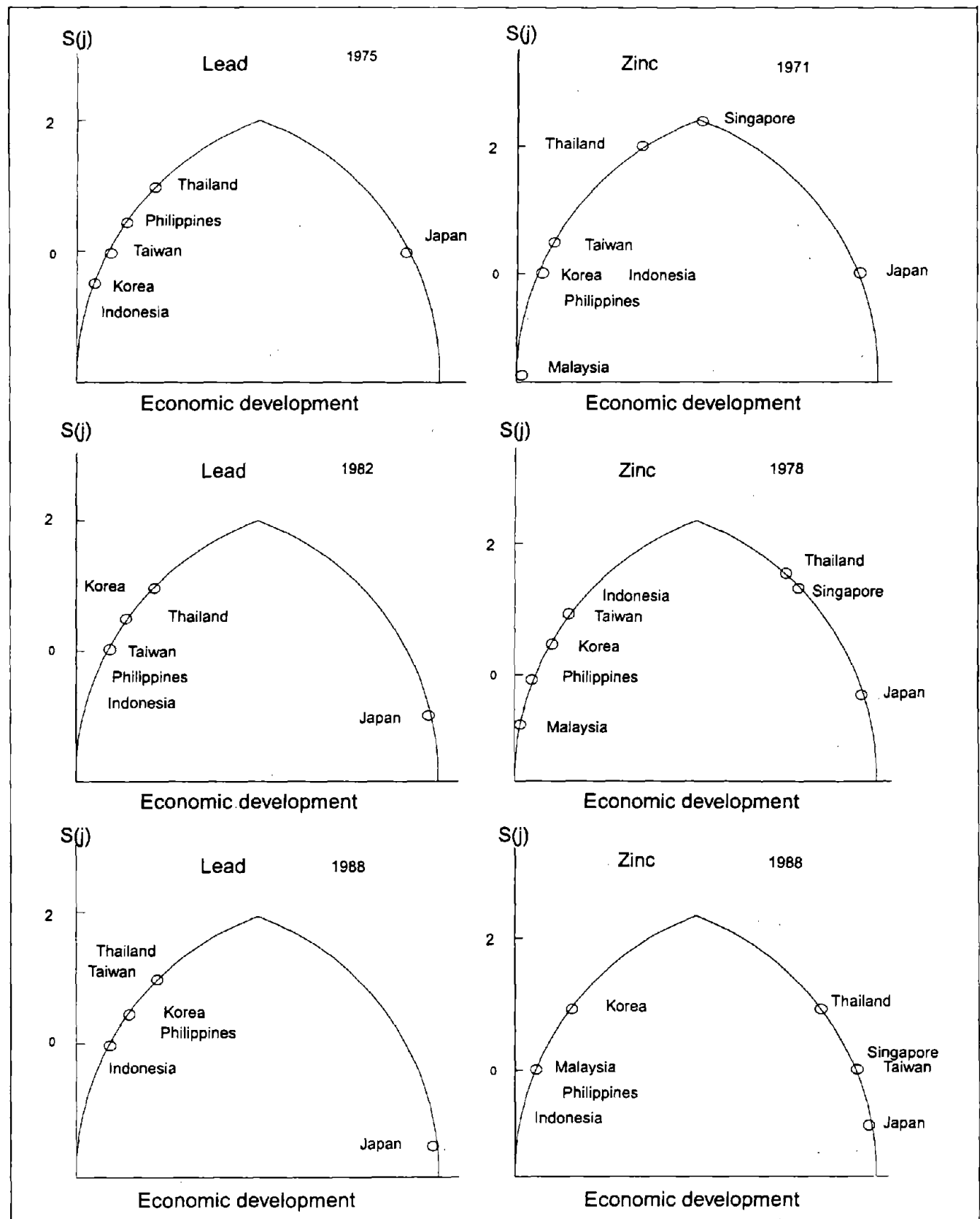


Figure 28.—Propensities to consume minerals because of intrasectoral structural changes—Continued.

down to the mid-point on the right-hand side of the curve. Meanwhile, Indonesia had moved up from the bottom of the left side of the curve to the mid-point, leaving only Singapore and the Philippines at the bottom. A similar reading can also be made from the rest of the panels in the figures for copper, lead, and zinc.

Individually, these panels of diagrams show where a country is relative to the others in terms of propensity to consume metals because of intrasectoral structural change in a given year. Collectively, they portray a dynamic picture of how the relative positions of the countries have changed over the years as a result of intrasectoral changes in the economic structures. What is more interesting, they can be used to check on the mineral intensity of use hypothesis.

The Asian Pacific Rim countries are generally considered to represent three levels of economic development. Japan is the only advanced country in the region. The ASEAN Four are the developing countries, and in between are the NIC's. Under the mineral intensity of use hypothesis, a country's mineral intensity of use would go up and down the inverted-U curve as a function of economic development. Thus if the hypothesis is right, a distribution pattern can be expected, showing Japan on the right-hand side of the curves, the ASEAN Four on the other side, and the NIC's somewhere in between.

The three panels for copper show that this, indeed, is the case. For aluminum, in 1971, the countries are grouped with Japan and Taiwan on the right, the Republic of Korea and Thailand in the middle, and the Philippines and the others on the left. By 1988, the grouping has become closer to the expected pattern with Japan on the right; Taiwan, the Republic of Korea, Thailand, and Malaysia in the middle; and Indonesia, the Philippines, and Singapore on the left. The unexpected observation is that Thailand and Malaysia had jumped ahead to join the NIC's and that Singapore was left out from that group.

The lead panel for 1975 shows a country grouping somewhat different from the expected pattern. But for 1988, the ranking has moved closer. The exceptions are, again, that Thailand had jumped ahead of the Republic of Korea to join Taiwan and that the Philippines had moved to join the Republic of Korea. The country distributions in the zinc panels would have conformed to the expected pattern had Thailand not jumped ahead to join the NIC's.

Thus the pattern of distributions is not consistently contrary to the mineral intensity of use hypothesis. In fact, if Thailand and Malaysia were put in the group of the NIC's, the country distributions in figure 28 would mostly conform to the expected pattern. The implication is that Thailand and Malaysia may have broken out of the rut of developing countries and edged closer to the NIC's in terms of economic development.

Figure 28 also shows that because a country's propen-

sity to consume minerals (attributable to intrasectoral structural changes) moves up and down the inverted-U curves as a function of economic development, the more advanced the country's economy is, the more cases in which the country is positioned on the top or right-hand side of the curves. Conversely, the less developed, the country's economy is, the more cases in which the country is positioned on the lower left-hand side of the curves. It is also clear that the same intrasectoral structure may not mean an equal propensity to consume for all minerals. Thus a country's positions on the curves at a given time generally vary. Those positions are good indicators of the country's cumulative consumption of the minerals (as required by the intrasectoral structure of the economy). The further to the right-hand side of the curves the positions are, the more minerals have been consumed accumulatively. In this sense, they indicate how important the minerals are relative to the others.

For example, figure 28 shows that Taiwan was on the right-hand side of the zinc curve and at the top of the aluminum and copper curves, but on the left-hand side of the lead curve in 1988. Meanwhile, Thailand was also on the right-hand side of the zinc curve and at the top of the aluminum curve, but low on the copper curve. Thus zinc, aluminum, and copper played more important roles than lead in Taiwan in 1988. In Thailand, zinc and aluminum were more important than copper, and in Singapore, zinc was far more important than aluminum. With their positions mostly situated on the lower left-hand side of all metals curves, the Philippines and Indonesia do not seem to have a metal of particular importance that can be associated with their economic development. On the other hand, all the four metals have played an important role in Japan as that country advances toward a post-industrial economy.

Although the analysis above does not contradict the mineral intensity of use hypothesis, there are methodological differences, and the study implications, therefore, are not exactly the same. What have been analyzed here in relation to economic development are the portions of the MIU attributable to intrasectoral structural changes, not the whole measures of MIU referred to by the mineral intensity of use hypothesis. In fact, this difference alone underscores the complexity of factors affecting mineral intensity of use and the inadequacy of using economic development alone as its sole predictor.

Having said this, it should be noted that the mineral intensity of use hypothesis is completely explicable by the study findings. In general, developed countries exhibit a declining MIU because the declining impact of the intrasectoral structural changes is reinforced by slower income growth and manufacturing expansion. On the other hand, developing countries exhibit a rising MIU because the rising impact of the intrasectoral structural changes is reinforced by faster income growth and manufacturing expansion.

## CONCLUSIONS

The two-tier modeling approach adopted in this study has enabled a rather unique analysis of the factors affecting minerals demand in the Asian Pacific Rim countries. The impacts of technological/price changes and intrasectoral structural changes on minerals demand have been separated from those of the other factors and quantified individually. The technological and price changes are found to have caused the demand for primary aluminum, lead, and zinc to decline. On the other hand, the intrasectoral structural changes have contributed positively to minerals demand, but the impact appears to increase in the early stage of economic development and decrease later in the advanced stage. The other factors analyzed are income and intersectoral structural changes, both contributing positively to minerals demand. Unfortunately, it is not possible to separate the impacts of these two variables because the proxy variables used to represent them are closely correlated with each other. Both of these variables tend to reinforce the influences of intrasectoral structural changes, producing a rising MIU in developing countries and a de-

clining MIU in developed countries. Thus to the extent that such reinforcements have worked, the analysis conforms to the mineral intensity of use hypothesis. The numerous factors analyzed, however, point to the inadequacy of using GDP alone as the predictor of MIU as implied by the mineral intensity of use hypothesis.

The estimated demand models can be used to forecast the future demands for the four metals in each of the nine countries. This, however, is not attempted in this study. Suffice it to say that the trends in technological and price changes probably will continue to cause substitution of aluminum, zinc, and lead. However, with income and the manufacturing share of GDP expected to continue to expand, demands for the four metals will increase more rapidly than the GDP in the ASEAN Four and the NIC's in the coming decade. Metals demand in Japan for the same reasons will also increase but at a rate lower than the GDP as its intrasectoral structural change continues to dampen mineral intensity of use.

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## APPENDIX

Table A-1.-Primary aluminum consumption by countries  
(In 1,000 metric tons)

| Year | Country |                   |        |           |           |          |          |             |           |
|------|---------|-------------------|--------|-----------|-----------|----------|----------|-------------|-----------|
|      | Japan   | Republic of Korea | Taiwan | Hong Kong | Singapore | Malaysia | Thailand | Philippines | Indonesia |
| 1962 | 184.2   | 0.2               | 8.5    |           |           |          |          |             |           |
| 1963 | 238.7   | 3.2               | 9.7    | 5.0       |           |          | 1.7      | 4.8         |           |
| 1964 | 265.3   | 0.2               | 12.8   | 7.6       |           |          | 2.4      | 4.5         |           |
| 1965 | 298.3   | 3.7               | 13.8   | 7.6       |           |          | 2.4      | 4.3         |           |
| 1966 | 393.4   | 4.7               | 14.8   | 7.2       |           |          | 3.9      | 7.2         |           |
| 1967 | 496.6   | 7.4               | 16.1   | 9.9       |           |          | 4.6      | 7.5         |           |
| 1968 | 621.1   | 8.5               | 20.3   | 13.5      |           |          | 5.2      | 9.3         |           |
| 1969 | 807.1   | 12.6              | 25.0   | 11.6      |           |          | 6.0      | 10.3        |           |
| 1970 | 911.4   | 15.3              | 34.2   | 15.2      |           |          | 8.4      | 10.5        |           |
| 1971 | 972.9   | 17.0              | 30.8   | 12.5      |           | 1.9      | 9.4      | 10.0        | 0.1       |
| 1972 | 1216.3  | 18.5              | 36.9   | 15.6      |           | 5.2      | 7.5      | 11.1        | 0.3       |
| 1973 | 1611.8  | 36.4              | 45.0   | 15.0      |           | 5.4      | 14.6     | 15.3        | 2.6       |
| 1974 | 1303.0  | 25.8              | 36.8   | 24.0      |           | 10.4     | 23.1     | 18.4        | 4.7       |
| 1975 | 1170.8  | 36.1              | 45.7   | 22.5      |           | 5.8      | 17.6     | 8.4         | 7.0       |
| 1976 | 1609.6  | 52.3              | 55.6   | 18.6      |           | 8.1      | 25.3     | 17.2        | 8.4       |
| 1977 | 1419.9  | 75.0              | 68.3   | 21.1      |           | 10.2     | 29.3     | 17.0        | 11.6      |
| 1978 | 1656.1  | 105.8             | 89.9   | 22.9      | 4.2       | 14.5     | 33.7     | 16.8        | 12.3      |
| 1979 | 1803.4  | 94.3              | 109.0  | 24.5      | 2.8       | 24.1     | 42.9     | 28.4        | 15.2      |
| 1980 | 1639.0  | 67.5              | 91.9   | 30.1      | 5.0       | 16.4     | 44.9     | 17.1        | 14.1      |
| 1981 | 1570.2  | 103.6             | 77.8   | 21.6      | 5.4       | 14.8     | 51.7     | 10.4        | 21.2      |
| 1982 | 1639.3  | 97.1              | 113.6  | 23.3      | 5.4       | 22.5     | 58.8     | 18.5        | 34.0      |
| 1983 | 1722.0  | 120.0             | 136.5  | 30.6      | 5.3       | 41.4     | 64.9     | 14.8        | 35.0      |
| 1984 | 1572.0  | 128.8             | 96.8   | 12.9      | 3.7       | 31.6     | 49.2     | 6.6         | 35.0      |
| 1985 | 1694.8  | 145.6             | 147.8  | 27.2      | 6.8       | 21.7     | 44.7     | 4.9         | 41.0      |
| 1986 | 1624.2  | 96.8              | 150.4  | 20.8      | 8.7       | 26.4     | 47.8     | 6.3         | 51.4      |
| 1987 | 1696.8  | 207.9             | 177.8  | 34.3      | 5.5       | 31.5     | 53.8     | 10.6        | 68.0      |
| 1988 | 2123.2  | 268.0             | 175.7  | 33.6      | 16.5      | 35.7     | 72.0     | 9.6         | 55.0      |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-2.-Refined copper consumption by countries**  
(In 1,000 metric tons)

| Year | Country |                   |        |          |          |             |           |
|------|---------|-------------------|--------|----------|----------|-------------|-----------|
|      | Japan   | Republic of Korea | Taiwan | Malaysia | Thailand | Philippines | Indonesia |
| 1962 | 281.2   |                   |        |          |          |             |           |
| 1963 | 352.1   |                   |        |          |          |             |           |
| 1964 | 457.5   |                   |        |          |          |             |           |
| 1965 | 427.5   |                   |        |          |          |             |           |
| 1966 | 482.5   |                   |        |          |          |             |           |
| 1967 | 616.0   |                   |        |          |          |             |           |
| 1968 | 695.2   |                   |        |          |          |             |           |
| 1969 | 806.9   |                   |        |          |          |             |           |
| 1970 | 820.6   |                   |        |          |          |             |           |
| 1971 | 805.7   | 8.7               | 7.7    |          |          |             |           |
| 1972 | 951.3   | 9.8               | 16.8   |          |          |             | 0.1       |
| 1973 | 1201.8  | 13.5              | 28.0   |          |          |             | 0.1       |
| 1974 | 808.9   | 23.5              | 28.6   |          |          |             | 0.3       |
| 1975 | 827.4   | 35.1              | 26.2   |          |          |             | 0.5       |
| 1976 | 1050.3  | 47.0              | 35.4   |          |          |             | 0.2       |
| 1977 | 1127.1  | 57.8              | 48.2   |          |          |             | 0.0       |
| 1978 | 1241.4  | 73.5              | 44.5   | 0.1      | 4.5      | 5.1         | 0.0       |
| 1979 | 1324.5  | 85.3              | 70.3   | 0.0      | 5.3      | 3.4         | 4.7       |
| 1980 | 1152.6  | 84.0              | 77.7   | 0.1      | 4.4      | 3.2         | 12.0      |
| 1981 | 1250.3  | 139.8             | 91.7   | 0.5      | 5.5      | 5.1         | 14.7      |
| 1982 | 1239.3  | 136.7             | 73.9   | 1.2      | 5.4      | 0.0         | 17.5      |
| 1983 | 1212.2  | 152.3             | 104.8  | 17.9     | 10.4     | 5.0         | 16.7      |
| 1984 | 1364.3  | 188.0             | 110.0  | 18.0     | 14.3     | 12.0        | 17.5      |
| 1985 | 1226.2  | 207.3             | 92.4   | 20.7     | 16.8     | 4.9         | 16.1      |
| 1986 | 1210.5  | 262.3             | 153.8  | 8.8      | 19.2     | 9.8         | 17.9      |
| 1987 | 1276.6  | 259.0             | 207.0  | 18.8     | 26.2     | 10.3        | 32.4      |
| 1988 | 1330.7  | 266.3             | 225.0  | 32.3     | 28.1     | 10.3        | 30.0      |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-3.-Zinc consumption by countries**  
(In 1,000 metric tons)

| Year | Country |                   |        |           |           |          |          |             |
|------|---------|-------------------|--------|-----------|-----------|----------|----------|-------------|
|      | Japan   | Republic of Korea | Taiwan | Hong Kong | Singapore | Malaysia | Thailand | Philippines |
| 1962 | 233.8   | 2.4               | 3.0    |           |           |          | 7.2      | 7.2         |
| 1963 | 304.7   | 7.1               | 3.8    | 3.4       |           |          | 9.3      | 7.8         |
| 1964 | 364.3   | 4.3               | 4.2    | 6.2       |           |          | 10.5     | 10.4        |
| 1965 | 329.5   | 9.2               | 5.7    | 1.3       |           |          | 9.1      | 11.0        |
| 1966 | 388.7   | 5.2               | 6.9    | 3.7       |           |          | 11.6     | 16.4        |
| 1967 | 461.8   | 8.5               | 10.6   | 4.5       |           |          | 16.7     | 16.3        |
| 1968 | 522.7   | 7.9               | 10.4   | 7.5       |           |          | 14.6     | 21.1        |
| 1969 | 599.9   | 9.0               | 10.0   | 8.2       |           |          | 18.3     | 21.7        |
| 1970 | 623.1   | 11.0              | 14.7   | 9.0       |           |          | 16.6     | 20.0        |
| 1971 | 624.1   | 13.9              | 17.6   | 8.4       | 6.6       | 2.3      | 18.9     | 15.1        |
| 1972 | 716.7   | 20.2              | 24.4   | 8.9       | 5.9       | 8.1      | 24.5     | 13.3        |
| 1973 | 814.9   | 23.1              | 24.4   | 9.8       | 5.1       | 8.8      | 21.4     | 11.8        |
| 1974 | 695.4   | 25.4              | 22.2   | 13.7      | 10.4      | 8.3      | 23.3     | 13.0        |
| 1975 | 547.1   | 27.6              | 12.3   | 9.2       | 7.6       | 6.5      | 17.6     | 9.4         |
| 1976 | 695.6   | 35.3              | 26.1   | 16.5      | 8.5       | 9.1      | 20.5     | 14.0        |
| 1977 | 716.8   | 46.3              | 27.9   | 14.6      | 9.4       | 9.0      | 29.3     | 18.8        |
| 1978 | 732.5   | 58.0              | 50.9   | 22.7      | 9.7       | 12.1     | 32.8     | 27.0        |
| 1979 | 778.6   | 72.7              | 37.3   | 24.3      | 14.4      | 13.7     | 33.6     | 26.5        |
| 1980 | 752.3   | 68.0              | 38.4   | 22.6      | 11.8      | 14.5     | 33.3     | 16.1        |
| 1981 | 699.1   | 74.4              | 43.3   | 32.4      | 12.0      | 11.5     | 38.1     | 19.3        |
| 1982 | 703.1   | 94.2              | 45.2   | 21.0      | 16.3      | 12.9     | 33.9     | 21.6        |
| 1983 | 770.8   | 109.0             | 56.6   | 23.1      | 12.1      | 14.8     | 36.3     | 24.4        |
| 1984 | 774.6   | 123.8             | 47.0   | 18.9      | 7.6       | 14.6     | 45.0     | 17.9        |
| 1985 | 780.1   | 119.7             | 49.4   | 21.5      | 6.4       | 14.6     | 39.6     | 13.0        |
| 1986 | 753.0   | 140.9             | 69.7   | 30.3      | 8.2       | 13.1     | 45.3     | 18.9        |
| 1987 | 728.7   | 178.7             | 74.6   | 18.0      | 7.0       | 16.4     | 48.9     | 20.5        |
| 1988 | 774.2   | 173.0             | 74.4   | 24.9      | 13.0      | 22.4     | 64.6     | 27.4        |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-4.-Lead consumption by countries**  
(In 1,000 metric tons)

| Year | Country |                   |        |           |          |             |
|------|---------|-------------------|--------|-----------|----------|-------------|
|      | Japan   | Republic of Korea | Taiwan | Hong Kong | Thailand | Philippines |
| 1962 | 117.7   | 5.0               | 3.0    |           | 3.0      |             |
| 1963 | 130.3   | 5.0               | 3.0    |           | 3.0      |             |
| 1964 | 164.2   | 6.0               | 4.0    |           | 3.0      |             |
| 1965 | 147.3   | 6.0               | 4.0    |           | 4.0      |             |
| 1966 | 147.9   | 6.0               | 4.0    |           | 4.0      |             |
| 1967 | 163.3   | 7.0               | 5.0    |           | 4.0      |             |
| 1968 | 180.7   | 7.0               | 5.0    |           | 4.0      |             |
| 1969 | 187.6   | 8.0               | 5.0    |           | 4.0      |             |
| 1970 | 210.5   | 8.0               | 6.0    |           | 5.0      |             |
| 1971 | 209.7   | 9.0               | 6.0    |           | 5.0      |             |
| 1972 | 231.0   | 10.0              | 7.0    |           | 5.0      |             |
| 1973 | 222.3   | 11.0              | 7.0    |           | 6.0      |             |
| 1974 | 263.7   | 11.6              | 7.5    |           | 6.0      |             |
| 1975 | 260.7   | 10.3              | 9.5    |           | 8.0      | 9.5         |
| 1976 | 309.7   | 10.6              | 13.8   |           | 9.3      | 8.3         |
| 1977 | 333.9   | 17.8              | 17.3   |           | 5.1      | 9.5         |
| 1978 | 352.1   | 27.3              | 24.2   |           | 8.1      | 11.0        |
| 1979 | 368.2   | 33.1              | 19.5   | 1.8       | 9.9      | 10.8        |
| 1980 | 392.5   | 33.0              | 16.1   | 1.7       | 13.1     | 8.8         |
| 1981 | 382.5   | 60.0              | 28.1   | 0.5       | 9.6      | 10.0        |
| 1982 | 354.0   | 41.7              | 29.1   | 2.1       | 12.2     | 11.7        |
| 1983 | 359.6   | 57.5              | 39.5   | 2.4       | 22.3     | 15.0        |
| 1984 | 390.7   | 57.4              | 40.6   | 1.2       | 18.6     | 6.7         |
| 1985 | 397.1   | 80.8              | 40.4   | 2.0       | 16.8     | 9.9         |
| 1986 | 389.6   | 88.3              | 58.6   | 4.8       | 18.6     | 11.4        |
| 1987 | 378.0   | 112.4             | 75.6   | 0.6       | 24.0     | 15.1        |
| 1988 | 406.5   | 146.0             | 74.8   | 4.9       | 27.0     | 11.6        |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-5.—Primary aluminum intensity of use by countries  
(Metric tons per million 1980 dollars GDP)**

| Year | Country |                   |        |           |           |          |          |             |           |
|------|---------|-------------------|--------|-----------|-----------|----------|----------|-------------|-----------|
|      | Japan   | Republic of Korea | Taiwan | Hong Kong | Singapore | Malaysia | Thailand | Philippines | Indonesia |
| 1962 | 0.606   | 0.014             | 1.138  |           |           |          |          |             |           |
| 1963 | 0.724   | 0.211             | 1.041  | 0.780     |           |          |          |             |           |
| 1964 | 0.721   | 0.012             | 1.332  | 1.095     |           |          |          |             |           |
| 1965 | 0.766   | 0.212             | 1.290  | 0.925     |           |          |          |             |           |
| 1966 | 0.912   | 0.241             | 1.212  | 0.825     |           |          |          |             |           |
| 1967 | 1.037   | 0.360             | 1.167  | 1.113     |           |          |          |             |           |
| 1968 | 1.149   | 0.374             | 1.225  | 1.471     |           |          |          |             |           |
| 1969 | 1.328   | 0.489             | 1.492  | 1.131     |           |          |          |             |           |
| 1970 | 1.354   | 0.549             | 1.591  | 1.354     |           |          |          |             |           |
| 1971 | 1.386   | 0.555             | 1.670  | 1.038     | 0.35      | 0.156    | 0.536    | 0.491       | 0.003     |
| 1972 | 1.599   | 0.572             | 1.765  | 1.167     | 0.30      | 0.390    | 0.411    | 0.516       | 0.007     |
| 1973 | 1.965   | 0.985             | 1.908  | 0.996     | 0.30      | 0.363    | 0.728    | 0.656       | 0.054     |
| 1974 | 1.608   | 0.642             | 1.542  | 1.559     | 0.30      | 0.645    | 1.103    | 0.752       | 0.091     |
| 1975 | 1.408   | 0.836             | 1.825  | 1.459     | 0.30      | 0.357    | 0.802    | 0.322       | 0.129     |
| 1976 | 1.847   | 1.070             | 1.950  | 1.030     | 0.30      | 0.447    | 1.054    | 0.612       | 0.145     |
| 1977 | 1.548   | 1.383             | 2.174  | 1.038     | 0.30      | 0.522    | 1.111    | 0.569       | 0.184     |
| 1978 | 1.718   | 1.759             | 2.519  | 1.029     | 0.43      | 0.696    | 1.156    | 0.533       | 0.180     |
| 1979 | 1.778   | 1.460             | 2.824  | 0.986     | 0.262     | 1.057    | 1.398    | 0.848       | 0.210     |
| 1980 | 1.547   | 1.078             | 2.219  | 1.092     | 0.427     | 0.670    | 1.396    | 0.485       | 0.181     |
| 1981 | 1.427   | 1.550             | 1.769  | 0.717     | 0.420     | 0.565    | 1.512    | 0.284       | 0.253     |
| 1982 | 1.449   | 1.354             | 2.495  | 0.750     | 0.393     | 0.811    | 1.652    | 0.491       | 0.407     |
| 1983 | 1.476   | 1.497             | 2.764  | 0.925     | 0.357     | 1.404    | 1.701    | 0.389       | 0.385     |
| 1984 | 1.283   | 1.469             | 1.773  | 0.356     | 0.230     | 0.995    | 1.204    | 0.185       | 0.360     |
| 1985 | 1.321   | 1.553             | 2.579  | 0.752     | 0.430     | 0.690    | 1.056    | 0.143       | 0.412     |
| 1986 | 1.235   | 1.867             | 2.350  | 0.514     | 0.540     | 0.829    | 1.081    | 0.182       | 0.488     |
| 1987 | 1.238   | 1.763             | 2.473  | 0.744     | 0.312     | 0.940    | 1.122    | 0.292       | 0.615     |
| 1988 | 1.466   | 2.043             | 2.277  | 0.680     | 0.842     | 0.979    | 1.308    | 0.249       | 0.470     |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-6.-Refined copper intensity of use by countries  
(Metric tons per million 1980 dollars GDP)**

| Year | Country |                   |        |          |          |             |           |
|------|---------|-------------------|--------|----------|----------|-------------|-----------|
|      | Japan   | Republic of Korea | Taiwan | Malaysia | Thailand | Philippines | Indonesia |
| 1962 | 0.925   |                   |        |          |          |             |           |
| 1963 | 1.068   |                   |        |          |          |             |           |
| 1964 | 1.243   |                   |        |          |          |             |           |
| 1965 | 1.097   |                   |        |          |          |             |           |
| 1966 | 1.120   |                   |        |          |          |             |           |
| 1967 | 1.287   |                   |        |          |          |             |           |
| 1968 | 1.286   |                   |        |          |          |             |           |
| 1969 | 1.327   |                   |        |          |          |             |           |
| 1970 | 1.219   |                   |        |          |          |             |           |
| 1971 | 1.148   | 0.284             | 0.417  |          |          |             |           |
| 1972 | 1.251   | 0.303             | 0.804  |          |          |             | 0.002     |
| 1973 | 1.465   | 0.365             | 1.187  |          |          |             | 0.002     |
| 1974 | 1.087   | 0.585             | 1.199  |          |          |             | 0.005     |
| 1975 | 0.995   | 0.813             | 1.046  |          |          |             | 0.009     |
| 1976 | 1.205   | 0.961             | 1.242  |          |          |             | 0.004     |
| 1977 | 1.229   | 1.066             | 1.534  |          |          |             | 0.000     |
| 1978 | 1.288   | 1.222             | 1.247  | 0.005    | 0.154    | 0.162       | 0.000     |
| 1979 | 1.312   | 1.321             | 1.821  | 0.000    | 0.172    | 0.102       | 0.065     |
| 1980 | 1.094   | 1.341             | 1.876  | 0.004    | 0.136    | 0.091       | 0.154     |
| 1981 | 1.140   | 2.092             | 2.085  | 0.019    | 0.161    | 0.139       | 0.175     |
| 1982 | 1.098   | 1.906             | 1.623  | 0.043    | 0.152    | 0.000       | 0.210     |
| 1983 | 1.042   | 1.900             | 2.122  | 0.607    | 0.273    | 0.131       | 0.184     |
| 1984 | 1.116   | 2.143             | 2.014  | 0.567    | 0.350    | 0.336       | 0.180     |
| 1985 | 0.959   | 2.210             | 1.612  | 0.658    | 0.397    | 0.143       | 0.162     |
| 1986 | 0.927   | 2.488             | 2.403  | 0.276    | 0.434    | 0.283       | 0.170     |
| 1987 | 0.937   | 2.197             | 2.880  | 0.561    | 0.547    | 0.284       | 0.293     |
| 1988 | 0.919   | 2.030             | 2.491  | 0.886    | 0.545    | 0.267       | 0.257     |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

**Table A-7.-Zinc intensity of use by countries  
(Metric tons per million 1980 dollars GDP)**

| Years | Country |                   |        |           |           |          |          |             |           |
|-------|---------|-------------------|--------|-----------|-----------|----------|----------|-------------|-----------|
|       | Japan   | Republic of Korea | Taiwan | Hong Kong | Singapore | Malaysia | Thailand | Philippines | Indonesia |
| 1962  | 0.769   | 0.172             | 0.402  |           |           |          | 0.832    | 0.592       |           |
| 1963  | 0.924   | 0.468             | 0.465  | 0.530     |           |          | 0.993    | 0.561       |           |
| 1964  | 0.990   | 0.259             | 0.458  | 0.893     |           |          | 1.051    | 0.723       |           |
| 1965  | 0.846   | 0.527             | 0.557  | 0.158     |           |          | 0.843    | 0.727       |           |
| 1966  | 0.902   | 0.267             | 0.619  | 0.424     |           |          | 0.959    | 1.037       |           |
| 1967  | 0.965   | 0.413             | 0.859  | 0.506     |           |          | 1.280    | 0.972       |           |
| 1968  | 0.967   | 0.348             | 0.772  | 0.817     |           |          | 1.032    | 1.192       |           |
| 1969  | 0.987   | 0.350             | 0.682  | 0.799     |           |          | 1.198    | 1.169       |           |
| 1970  | 0.926   | 0.394             | 0.900  | 0.698     |           |          | 0.993    | 1.031       |           |
| 1971  | 0.889   | 0.454             | 0.954  | 0.698     | 1.185     | 0.189    | 1.077    | 0.742       | 0.223     |
| 1972  | 0.942   | 0.625             | 1.215  | 0.666     | 0.935     | 0.608    | 1.341    | 0.619       | 0.345     |
| 1973  | 0.993   | 0.625             | 1.034  | 0.651     | 0.726     | 0.591    | 1.067    | 0.506       | 0.412     |
| 1974  | 0.858   | 0.632             | 0.930  | 0.890     | 1.387     | 0.515    | 1.113    | 0.531       | 0.311     |
| 1975  | 0.658   | 0.639             | 0.491  | 0.596     | 0.975     | 0.400    | 0.802    | 0.361       | 0.370     |
| 1976  | 0.798   | 0.722             | 0.916  | 0.913     | 1.018     | 0.502    | 0.854    | 0.498       | 0.486     |
| 1977  | 0.781   | 0.854             | 0.888  | 0.718     | 1.045     | 0.461    | 1.111    | 0.630       | 0.579     |
| 1978  | 0.760   | 0.964             | 1.426  | 1.020     | 0.993     | 0.581    | 1.126    | 0.857       | 0.655     |
| 1979  | 0.768   | 1.126             | 0.966  | 0.978     | 1.348     | 0.601    | 1.095    | 0.792       | 0.638     |
| 1980  | 0.710   | 1.086             | 0.927  | 0.820     | 1.006     | 0.592    | 1.035    | 0.457       | 0.659     |
| 1981  | 0.635   | 1.113             | 0.985  | 1.075     | 0.934     | 0.439    | 1.114    | 0.527       | 0.781     |
| 1982  | 0.621   | 1.314             | 0.993  | 0.676     | 1.187     | 0.465    | 0.952    | 0.573       | 0.785     |
| 1983  | 0.660   | 1.360             | 1.146  | 0.699     | 0.815     | 0.502    | 0.951    | 0.641       | 0.759     |
| 1984  | 0.632   | 1.412             | 0.861  | 0.522     | 0.473     | 0.460    | 1.101    | 0.501       | 0.464     |
| 1985  | 0.608   | 1.411             | 0.861  | 0.522     | 0.472     | 0.464    | 0.936    | 0.380       | 0.508     |
| 1986  | 0.573   | 1.336             | 1.089  | 0.749     | 0.509     | 0.412    | 1.024    | 0.545       | 0.459     |
| 1987  | 0.532   | 1.516             | 1.038  | 0.390     | 0.397     | 0.489    | 1.020    | 0.564       | 0.440     |
| 1988  | 0.535   | 1.319             | 0.964  | 0.504     | 0.663     | 0.614    | 1.174    | 0.710       | 0.496     |

Source: Metal Statistics, various issues. Metallgesellschaft Aktiengesellschaft.

**Table A-8.-Lead intensity of use by countries**  
(In metric tons per million 1980 dollars GDP)

| Year | Country |                   |        |          |             |           |
|------|---------|-------------------|--------|----------|-------------|-----------|
|      | Japan   | Republic of Korea | Taiwan | Thailand | Philippines | Indonesia |
| 1962 | 0.387   | 0.358             | 0.402  | 0.347    |             |           |
| 1963 | 0.395   | 0.329             | 0.367  | 0.320    |             |           |
| 1964 | 0.446   | 0.362             | 0.437  | 0.300    |             |           |
| 1965 | 0.378   | 0.344             | 0.391  | 0.371    |             |           |
| 1966 | 0.343   | 0.308             | 0.359  | 0.331    |             |           |
| 1967 | 0.341   | 0.341             | 0.405  | 0.307    |             |           |
| 1968 | 0.334   | 0.308             | 0.371  | 0.283    |             |           |
| 1969 | 0.309   | 0.311             | 0.409  | 0.327    |             |           |
| 1970 | 0.313   | 0.287             | 0.367  | 0.299    |             |           |
| 1971 | 0.299   | 0.294             | 0.325  | 0.285    |             |           |
| 1972 | 0.304   | 0.309             | 0.334  | 0.274    |             |           |
| 1973 | 0.271   | 0.298             | 0.297  | 0.299    |             |           |
| 1974 | 0.325   | 0.289             | 0.314  | 0.287    |             |           |
| 1975 | 0.314   | 0.238             | 0.379  | 0.364    | 0.365       | 0.072     |
| 1976 | 0.355   | 0.217             | 0.484  | 0.387    | 0.295       | 0.059     |
| 1977 | 0.364   | 0.328             | 0.551  | 0.193    | 0.318       | 0.078     |
| 1978 | 0.365   | 0.456             | 0.678  | 0.278    | 0.349       | 0.126     |
| 1979 | 0.363   | 0.512             | 0.505  | 0.322    | 0.323       | 0.094     |
| 1980 | 0.371   | 0.527             | 0.389  | 0.407    | 0.250       | 0.120     |
| 1981 | 0.348   | 0.898             | 0.639  | 0.281    | 0.273       | 0.117     |
| 1982 | 0.313   | 0.581             | 0.639  | 0.343    | 0.311       | 0.103     |
| 1983 | 0.308   | 0.717             | 0.800  | 0.584    | 0.394       | 0.130     |
| 1984 | 0.319   | 0.654             | 0.743  | 0.455    | 0.188       | 0.134     |
| 1985 | 0.309   | 0.862             | 0.705  | 0.397    | 0.289       | 0.147     |
| 1986 | 0.296   | 0.838             | 0.916  | 0.421    | 0.329       | 0.201     |
| 1987 | 0.276   | 0.953             | 1.052  | 0.501    | 0.416       | 0.137     |
| 1988 | 0.281   | 1.113             | 0.969  | 0.491    | 0.301       | 0.137     |

Source: Metal Statistics, various issues, Metallgesellschaft Aktiengesellschaft.

