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The Iron and Steel Industry in Asia: Development and Restructuring

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Abstract

The paper examines the development and restructuring of the iron and steel industry in Asian countries. Studying countries that have integrated steelworks with large blast furnaces (South Korea, Taiwan, China and India) and countries without (Thailand, Indonesia and Malaysia), the paper shows the difference in the development processes across the countries and across time, and points to the diversity of the development experience of these countries. The paper argues that significant differences in steel production technologies in terms of initial investment and minimum-efficient scale, the changing role of the state, and shifting demand structures in the domestic steel markets of each country have been the important factors that led to the differences in the development path of the steel industry in each country.

Keywords: steel, industrial development, Asia
JEL classification: L52, L61, N65, O14

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The Iron and Steel Industry in Asia: Development and Restructuring[1]

1 Introduction

Since the turn of the millennium, the world's steel industry has experienced significant change. First, global crude steel production per annum increased to around 120 million tonnes by 2006, after having fluctuated at around 80 million tonnes for nearly three decades from the early 1970s to around 2000.[2] Second, a transnational restructuring of big steel firms has been taking place as exemplified by the acquisition in 2006 of Arcelor, the second largest steel firm in the world, by Mittal, the largest, and the takeover of Corus by Tata Steel in 2007.

The backdrop to these phenomena was changes that took place during the period of long stagnation in steel production from the early 1970s to around 2000. One factor was changes in the international division of labor in steel production. In 1975 the USA, the EU(15), the USSR and Japan produced 78% of the world's total crude steel. In 2005 the share of these countries had decreased to 43% while the steel industries in developing countries increased their share of global crude steel production. Steel production in Asian countries in particular has shown a significant rise, and in 2005 Asia's share of world crude steel production reached over 50%.[3]

Therefore, the paper highlights the steel industry in Asia and seeks to analyze the features and factors in the development processes of Asia's steel industry.[4] In so doing, it also aims to study the relationship of industrial policy, economic development and the development of the steel industry, and to examine the changes in technology, demand and trade patterns. In other words, the paper seeks to present the diversified development processes of the steel industry in each country and, at the same time, to extract the factors that are shared by each country as well as those factors that have brought about differences in the development processes of each country.

The next section discusses the debate over the East Asian development experience and how the steel industry has been studied and treated in this debate.

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[1] This paper is a revised, shortened and translated version of Chapter 1 of Sato ed. (2008a) which is the introductory chapter of the book.

[2] Statistics in this paper are from International Iron and Steel Institute (IISI), *Steel Statistical Yearbook* (various issues), unless otherwise indicated.

[3] In this paper, Asia includes East Asian, Southeast Asian and South Asian countries.

[4] The study covers the development of the industry up to the mid-2000s (around 2006).

The third section depicts the technologies of steel production, and the features of the steel industries in Asian countries. Section 4 summarizes the country analyses that examined the development processes of the steel industry in each country and discusses the findings of the study.

2. The Steel Industry and the Debate over Industrial Development in East Asia

Often called the 'rice of industries' in Japan, the steel industry forms the foundation for heavy and chemical industrialization. Therefore, it is useful to situate sectoral studies on the steel industry in the broad context of the debate over the East Asian development experience, especially regarding its industrialization processes.

The two main aspects in the debate over East Asia's development experience have been the role of productivity or technology in economic growth and the role of government. Some have argued that economic growth in Asian countries has depended upon additional inputs of labor and capital rather than technological progress (e.g. Krugman, 1994), while others have insisted that there has been significant technological growth through foreign direct investment (FDI) inflow (e.g. Pack and Page, 1994). The difference between them lies partly in their different understandings of technological progress. Advocates of the former focus on original technological innovation while the latter point to the importance of absorption and diffusion of technology. Therefore, the former consider that there has been no convergence with regard to the technological gaps between advanced and developing countries while the latter imply that developing countries have made a significant catch-up.

Regarding the role of government, nobody denies the presence of government intervention in the process of rapid industrial development in Asian countries. However, the essence of the debate is that the neoclassical economic approach points to the role of the free market and trade (price signals) for allocating scarce resources while the developmental state approach stresses the role of the state in resource allocation. This difference in view has led to the debate over the content of industrial policy. The neoclassical market-friendly approach in general stresses export-oriented policy and justifies state intervention only in the case of market failure (e.g. World Bank, 1993), while the developmental state approach argues that the role of the state goes beyond the case of market failure and that import-substitution policy has also been important in addition to the export-oriented policy (e.g. Amsden, 1989).

In this debate over industrial development in Asia, sectoral studies focusing on each sector have provided detailed case studies of the processes of technological upgrading or of the role of government that differ across industries. In the case of the sectoral studies on the steel industry, two features are worth mentioning.

First, the case studies of the steel industry have pointed to the importance of learning or absorption of imported technology. Innovation in steel production and in steel products has not been important in developing countries. Rather, how developing countries have been able to introduce the established systems of modern steel production has been the main issue. As such, technological choices and entrepreneurship have been the main aspects of academic interest. The focus of study has been placed especially on mega-projects involving the introduction of integrated steelworks (e.g. Amsden, 1989; Shin, 1996; D'Costa, 1999). South Korea has been studied as a successful example and India as a less-successful case. In contrast, medium and small-sized steel production systems such as electric arc furnaces and rolling mills have tended to be overlooked in the literature to date.

Second, closely related with the first point, case studies of the steel industry have focused on the capability of the government as the main factor for success or failure. Without exception in developing countries mammoth steel projects have been pursued as state projects. This is because the introduction of integrated steelworks necessitates large initial investment, and in general no actors other than the state are able to bear the burden of such risky enterprises. As a result, it has been argued that the ability of the state is the key factor affecting the outcome of such projects (D'Costa, 1999). Thus, the case studies of the steel industry provided an argument for the state rather than the market.

In contrast, Kawabata (2005) examines the development processes of the steel industry in East Asian and ASEAN countries by dividing them into the countries that have integrated steel production and those without. Through an examination of the trade structures, the study reveals the hierarchal structure between the two groups. In effect, the study adopts an approach that can study various types of steel production and firms and the international division of labor in steel production. At the same time, in addition to the production processes, it also includes demand-side issues by incorporating the hierarchy in steel markets from high to low value-added products. As a result, the study depicts the relationship between producers and the segmented steel markets, and in so doing, points to the issues related to the level of economic development. One remaining task of the study is to analyze differences among the countries that belong to the same group.

In short, an important task is to study the development of the steel

industry in developing countries with emphasis on technology other than integrated steel production, and to examine differences among the countries through studying the industry as a whole in terms of both production and exchange spheres.

3. The Features of the Steel Industry in Asian Countries

The section discusses the tasks and approaches of this paper. At the same time, it provides important information on steel production technology and types of firms which is preliminary to conducting case studies on the steel industry. Furthermore, it summarizes the specific features of the steel industry in each Asian country regarding supply and demand structures, and in so doing, presents issues to be examined. The approach of the paper is by country because the development of the steel industry has been heavily depended upon the level of economic development and industrial policy of each nation-state. The countries analyzed in the paper are South Korea, Taiwan, China, India, Indonesia, Thailand, and Malaysia.

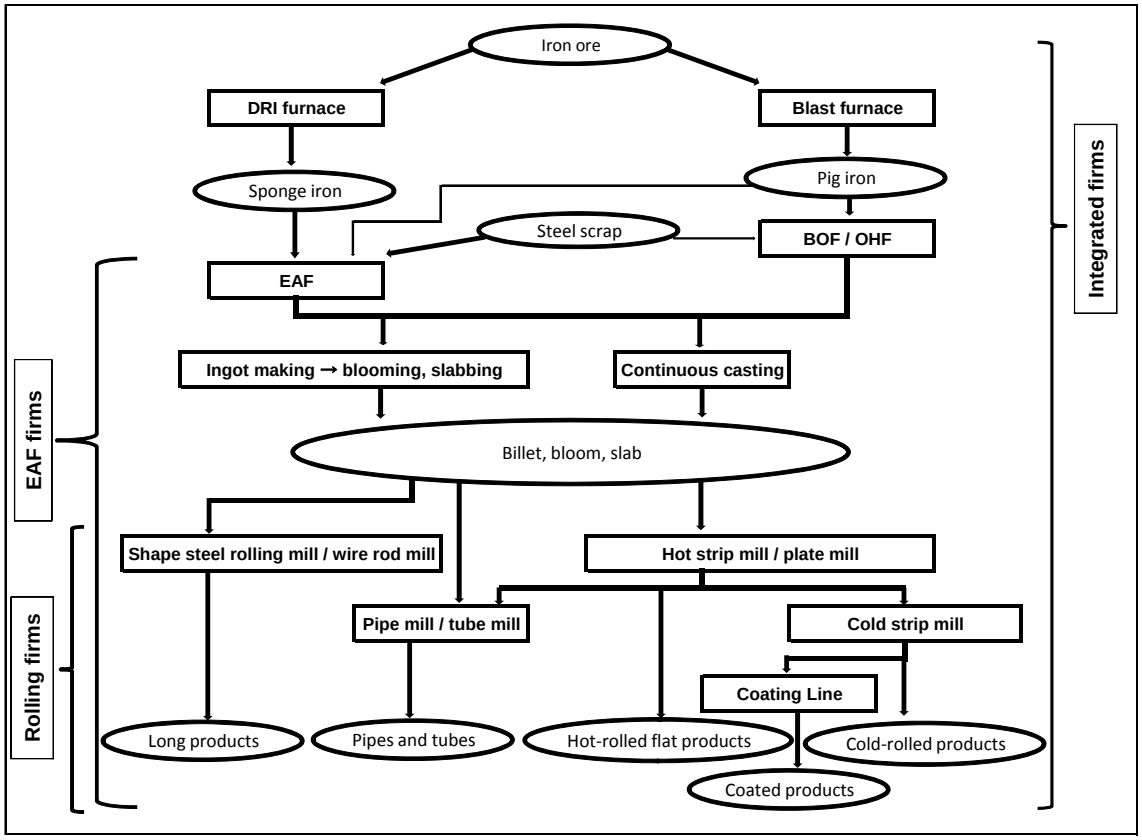
This section is organized in five sub-sections: (1) production of technology and types of firms, (2) actors, (3) the level of economic development and steel demand, (4) the relationship between steel supply and demand, and (5) imports of flat-steel products. Sub-sections 1 and 2 examine the issues of technology and the role of government that have been heavily disputed in East Asian industrial development, with specific reference to the steel industry. Sub-sections 3 and 4 depict the relationship between the level of economic development and steel supply and demand, and present the features of the steel industry in each Asian country. Sub-section 5 describes the import structure of flat-steel products in each Asian country, because the international production network for these products is relatively apparent..

3.1 Production technology and firm type

This paper studies not only integrated firms but also other types of firms, thus uses firm typology that depends on the steel production process.[5] This typology is also useful for analyzing technological choice. Figure 1 depicts the production process of steel as well as firm categories.

[5] For the detail of this framework, see Okamoto (1984) and Kawabata (2005), for example.

Figure 1 Production flow and firm type



Source: Author
Note: Rectangles indicate major production facilities, while the ovals depict inputs and/or outputs.

Firm type

There are basically three stages in steel production: iron making, steel making and rolling (including surface treatment), and there are mainly three types of firms.

One type is a steelworks that has all three stages and is called an integrated steelworks. A firm that has one or more integrated steelworks is called an integrated firm. An integrated firm produces pig iron by using iron ore as input for blast furnaces, then converts this to crude steel using basic oxygen furnaces (BOF) or open hearth furnaces (OHF). The first generation of integrated steelworks was installed inland close to iron ore mines or coal mines, and had blast furnaces, OHFs, ingot making, blooming (and/or slabbing), and rolling machines.[6] This production system was established in the late 19th century and is still being used in some countries. The second generation that came into existence in the 1960s is located in deep water ports, has large blast furnaces, BOFs, continuous casting (CC)

[6] See Kawabata (2007) for a discussion on the types of integrated steelworks.

machines and hot-strip mills and other rolling machines. The second generation of integrated steelworks is characterized by much higher productivity, scale economies and mass production than the first generation. The production system uses coking coal as a reducing agent. As this technology reduces iron ore by adding carbon (to make pig iron) then reduces carbon (to make steel), it is known as the indirect method.

There is another type of integrated firm that uses what is known as the direct method which reduces iron ore to sponge iron (directly reduced iron: DRI, or hot briquette iron: HBI) by using natural gas or low-grade coal as a reducing agent. Then electric arc furnaces (EAF) are used for making steel from sponge iron. Integrated firms using the direct method have DRI furnaces, EAFs and rolling machines. The capacity of this type of integrated steelworks is medium size. Integrated firms using the indirect method produced 880 million tonnes of pig iron worldwide in 2006; in contrast, the global production of DRI was 60 million tonnes, even though the latter has been growing since the early 1990s.[7]

The second type of steelworks is the semi-integrated firm that has steel-making and rolling processes in its plants. This is often called an EAF firm (minimill), for it makes crude steel out of steel scrap or DRI in EAFs and rolls it in rolling machines. Sometimes EAF firms have their steel-making plant and rolling plant separated. It is technologically difficult for integrated steel production with blast furnaces to adjust to cyclical demand whereas the EAF method is flexible to operate.

The third type of steelworks is the rolling firm. Rolling firms purchase semi-finished steel products, such as billets and slabs, and specialize in hot-rolling and/or cold-rolling processes.[8] There are also firms that specialize in surface treatment, such as galvanizing, color-coating and tin-coating lines, or in making tubes and pipes. These are not rolling firms per se but are often included in the category of rolling firms. Coil centers and wire making firms are sometimes categorized as part of the steel industry, but conventionally they are treated as secondary makers that are not included in the industry.

Technologically and theoretically there could be firm types that specializes in iron making only, steel making only, or in both iron and steel making processes. However, there are few such firms because of cost efficiency due to the heavy weight of raw materials for steel production and wastage of heat energy. Yet there were

[7] It should be noted that there are a few firms that have their steel-making plant and rolling plant separated. This is an integrated firm, however, it is not integrated in terms of production.

[8] In the case of cold rolling, the mother products are hot-rolled coils.

such exceptional firms in countries such as India and Malaysia that played an important role in the development process of the steel industry.

The features of steel production technology and steel products

In addition to affecting firm types, steel production technologies in themselves have different features. Iron making and steel making are characterized by chemical reaction and plant-based technology. In contrast, rolling processes are more like the machinery industry as the processes adjust the shape and surface of steel products. The capital-intensive character of each process limits the possibility of substituting capital inputs with low-wage, labor-intensive methods.

It is important to distinguish long-steel and flat-steel products. Long products are generally used by the civil engineering and construction industry, and they are relatively difficult to differentiate compared to flat products. Domestic demand for long products, especially from government public works, is often crucial especially in developing countries. Exporting these products is often not competitive due to freight costs; thus a decrease in domestic demand is not likely to trigger exports, but result instead in a decrease in production operations.

Unlike long products, qualitative differences among flat products are relatively large from high value-added ones used for automobiles and electronics to general usage products such as pipes. As a result, the hierarchical division of product markets is more apparent than for long products. It is also difficult to control quality in the rolling process, thus synthesized quality control from iron making to rolling is required. For this reason integrated firms tend to have a competitive advantage in flat products. Therefore, exports and imports through product differentiation and international production networks of integrated firms are important factors in the flat-steel sector. In other words, in general there is more room for evolving an international division of labor in flat products than in long products.

Initial investment and minimum-efficient scale for each technology

Each technology has a different initial investment and minimum-efficient scale of production.[9] For example, a bar mill can operate on 0.1 million tonnes per annum; in contrast, the minimum-efficient scale of a hot-strip mill is more than 2 million tonnes. Also, for the former, the initial investment is reported to be around US$20 million and the latter US$400 million. In the case of EAF firms, the minimum-efficient scale is 0.3 million tonnes and the initial investment US$100

[9] See Kawabata (2005) Chapter 1.

million. For an integrated steelworks, the minimum-efficient scale is 3 million tonnes per annum and a US$4,000 million initial investment.

An alternative technology to an integrated steelworks for producing flat products is the EAF firm with thin slab CC. Its minimum-efficient scale is 1 million tonnes and an initial investment of US$300 million. However, for EAF firms that principally depend on steel scrap as input, it is difficult to produce flat products of sufficient quality. Also, for a rolling plant with hot-strip mills, capacity enlargement and vertical integration is possible by adding blast furnaces and BOF later, but for a plant with EAFs and thin slab CC, it can only add direct reduction furnaces in its upstream process (its minimum-efficient scale is around 1 million tonnes and an initial investment of US$100 million) because it is technologically difficult to integrate a blast furnace and an EAF.

In short, there are hierarchical gaps among technologies in terms of initial investment and minimum-efficient scale. Rolling plants for long products are the cheapest in terms of initial investment, then plants with EAFs and rolling mills for long products come next. Compared to these plants, steelworks with EAFs and thin slab CC and plants with hot-strip mills necessitate significantly higher initial investment. Investment for introducing an integrated steelworks requires far higher outlays. In addition to the initial investment, market size and the quantitative balance between supply and demand in each segment of the steel market become important for the technological choices according to the minimum-efficient scale of each technology.

3.2 Actors

As noted earlier, the literature to date has focused on integrated firms as the main actors in the development of the steel industry. The present study conducts a broader examination in order to shed light on other actors in the steel industry such as EAF firms and rolling firms. They can be either local firms or foreign ones, but the paper focuses more on the former. The role of government is also important as a direct actor (state-owned firms) or through official policy measures.

Steel production facilities differ in terms of minimum-efficient scale and the amount of initial investment, thus markets into which domestic firms can enter differ across countries and time. In general, it has been considered that state-owned integrated firms play the core role in the development of the steel industry in late industrializing countries. However, the development of steel production other than that of integrated production might be different and should be examined. In cases

where state-sponsored integrated steel plants have played the critical role in the development of the industry, changes afterwards such as privatization and their underlying factors become issues to be studied.

The role played by foreign firms is another important issue that has aspects, such as technological introduction and transfer, investment procurement, and the international division of labor and production networks of incumbent big firms from advanced countries. The role of foreign firms is also greatly affected by state policy towards FDI. Therefore, the relationship of local state-owned firms, local private firms and foreign firms in the steel industry and its transformation needs to be examined.

Industrial policy in the broadest sense includes investment coordination among industries (e.g. big-push policy and economic planning), industry-specific investment coordination (e.g. entry regulation, credit allocation, recession cartels, price regulation), and industry-neutral measures (e.g. exchange rate and inflation). The effects of various policies on the development of the steel industry have to be looked at. More concretely, state intervention can be identified in various aspects of the steel industry, for example in the production sphere, procurement of finance and raw materials, provision of infrastructure, technological transfer or imports, ownership patterns, and labor management, and in the exchange sphere, price regulation of steel products, trade, demand creation, and industrial structure. Therefore, their effects should be carefully examined. Needless to say, it is impossible to study every policy and its effect in detail, therefore, the focus should differ according to country and timeframe.

3.3 Economic development and steel demand

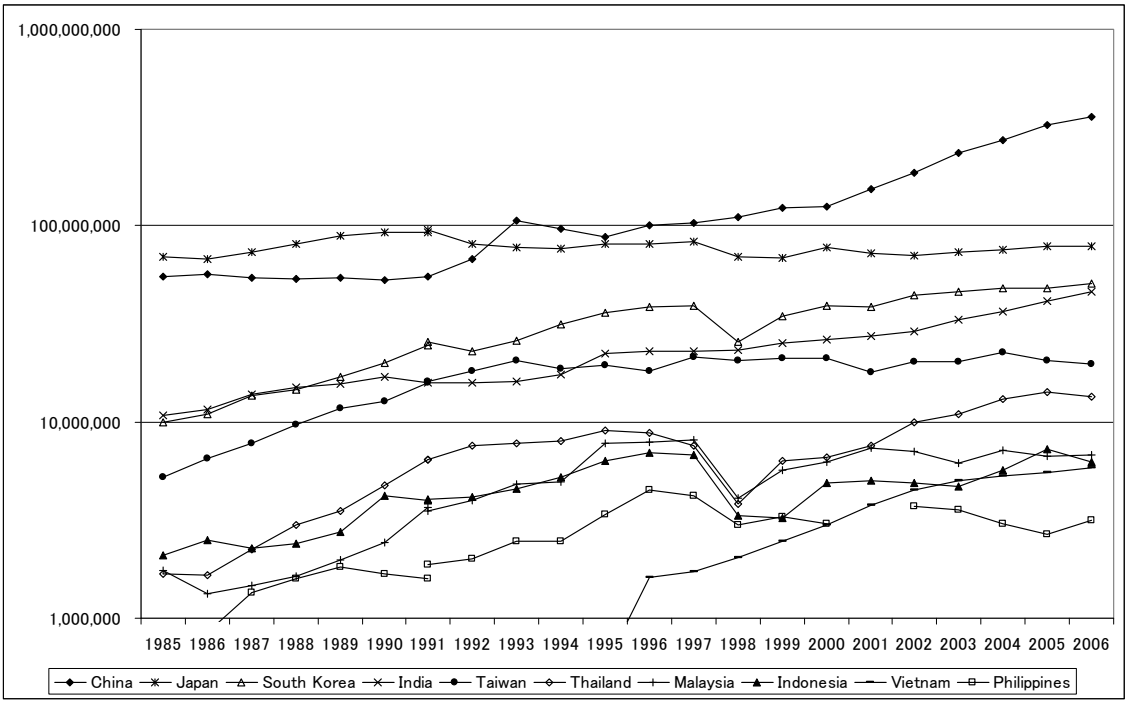
The scale of domestic steel demand sets a basis for technological choice. This is because steel products, notably long products, tend to be sold domestically, and the minimum-efficient scale of production differs depending on technology. Furthermore, the segmentation of the steel market is related to the level of economic development. Therefore, the backward linkage from the steel-using industries is an important factor for the development of the industry. In order to clarify these points, the domestic steel demand structures of the Asian countries will be examined here.

Figure 2 shows the trend of consumption of finished products in ten of the Asian countries studied. From the 1990s, China, India and Vietnam recorded constant increase, and steel demand in China increased five times from 1990 to 2000 while that in India doubled during the same period. Among the countries that

were affected by the East Asian financial crisis, demand in South Korea and Thailand after the crisis exceeded the level achieved before the crisis, while steel demand in Indonesia, Malaysia and the Philippines has not recovered to the level achieved before the crisis. Steel demand in Japan and Taiwan has been stable.

Figure 2 Apparent consumption of finished steel products (1985-2006)

(Tonnes)



Sources: For China and India: International Iron and Steel Institute (IISI), *Steel Statistical Yearbook (SSY)* (various issues). For the remaining countries: South East Asia Iron & Steel Institute (SEAISI), *Steel Statistical Yearbook (SSY)* (various issues) for the data after 1991; IISI, *SSY* (various issues) for the data from 1985-1991.

Note: The data are plotted against the logarithmic scale.

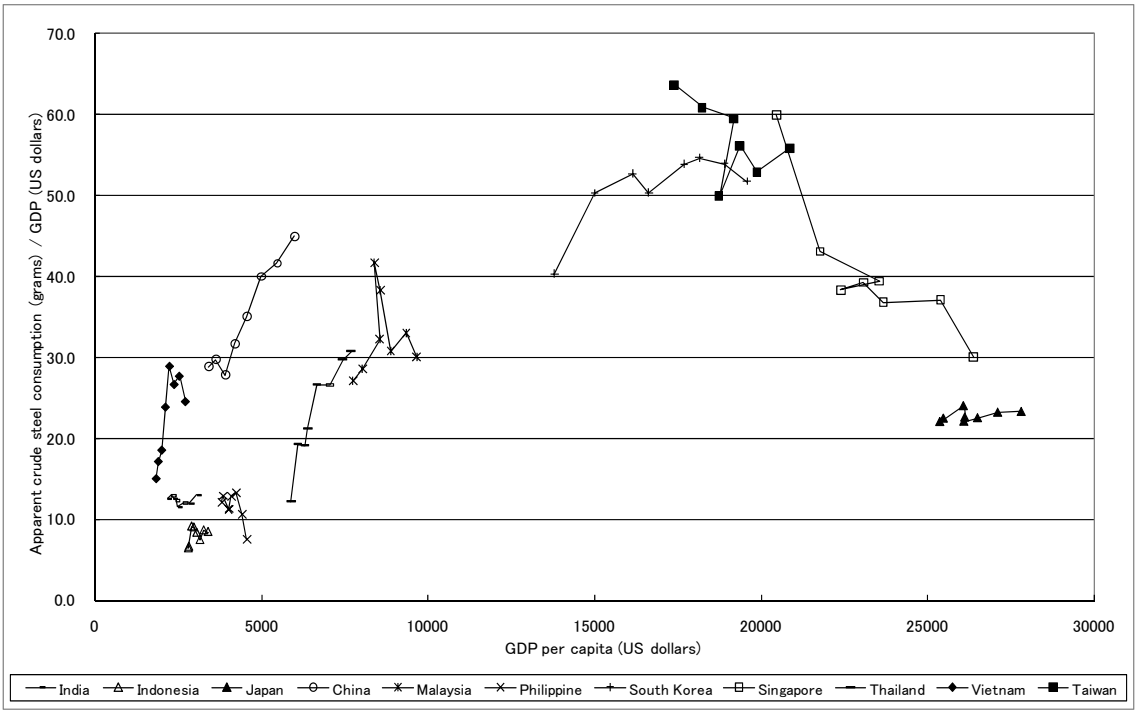
Figure 3 plots the trends in steel intensity, which is steel consumption per GDP, against the GDP per capita for the 1998-2005 period, in order to observe the relationship between the level of economic development and steel consumption.[10] In general, steel intensity increases as GDP per capita rises, and peaks at around US$15,000-20,000, then decreases as the GDP per capita further increases, showing an inverse U shape. This is because in a maturing economy, substitutes such as plastics come to prevail and steel usage per commodity tends to decrease. As clearly observed from Figure 3, in Thailand, China and Vietnam, steel intensity has been increasing as the economy grows. In South Korea and Taiwan it seems their steel intensities are around the peak, and Singapore is now at the stage where steel

[10] For a detailed discussion on steel intensity, see Toda (1984) and Kawabata (2005).

intensity is decreasing. Japan's steel intensity is at a decreased but stable level, while in India it seems steel intensity is about to take off. However, in Indonesia, Malaysia and the Philippines, steel intensity has stagnated or begun decreasing well before the GDP per capita reached US$15,000. This indicates that the relationship between the level of economic development and steel consumption cannot necessarily be explained by the inverse U hypothesis, and suggests the need for detailed country-specific study.

Figure 3 Steel intensity (1998-2005)

(Grams/US dollars)



Source: Apparent crude steel consumption (excluding Taiwan's) is derived from IISI, *SSY* (2007), GDP and GDP per capita from World Bank, *World Development Indicator* (2007 CD-ROM). For Taiwan, GDP and GDP per capita (1998-2004) are taken from Penn-World Tables.

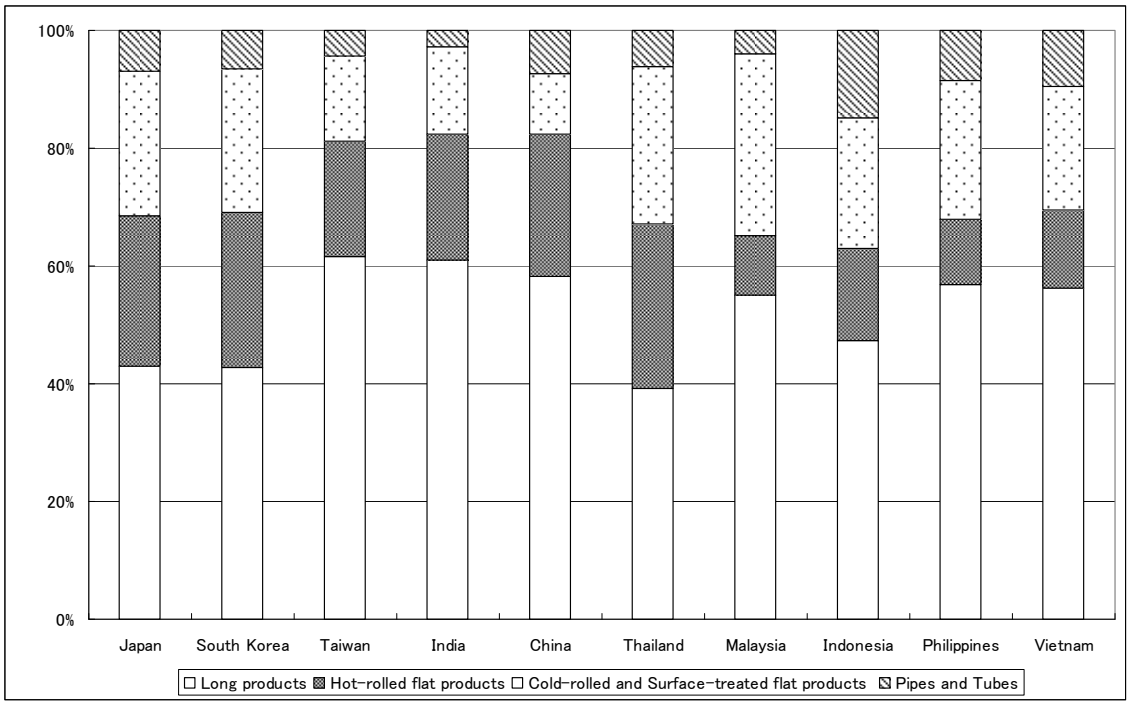
Note: GDP and GDP per capita are in PPP constant 2000 international US dollars.

The composition of steel demand for each Asian country is shown in Figure 4. In general, the higher the ratio of flat products (hot-rolled coils, cold-rolled coils, and pipes and tube) to total finished products, the higher the industrial structure of a country's domestic economy. In Japan, South Korea and Thailand this ratio is around 60% while in China, India and Taiwan it is around 40%. Why this ratio is so high in Thailand, and why low in Taiwan is an important question to study because this casts doubt on a single-track hypothesis that steel demand structure shifts from low to high value-added products as an economy grows. For Malaysia,

Indonesia, the Philippines and Vietnam, the ratios of flat products are between the two extreme groups. These findings suggest that the relationship between the demand structure for steel products and the level of economic development should be examined in terms of history- and country-specific features. Also the providers of these steel products to each sector of the steel market need to be studied carefully.

Figure4 Composition of steel demand by product (2006)

(%)



Source: Figures for China are derived from China Iron and Steel Association (CISA), *Steel Statistical Yearbook (SSY)* (2006), India from Joint Planning Committee (JPC), *mimeo*, and the remaining countries from SEAISI, *SSY* (2007).

Note 1: Figures for China are for 2005, for India fiscal year 2005/06, for Vietnam 2004.

Note 2: The duplicate counting of hot-rolled flat products used as input for cold-rolled products or pipes and tubes and that of cold-rolled flat products used as input for surface-treated products has been deducted.

3.4 Steel production and supply and demand

Steel production is driven not only by domestic demand but also by foreign demand (exports). In other words, the level of import substitution can be seen by examining the extent that domestic demand is supplied by domestic production, while export-oriented development can be measured through observing the extent that foreign demand drives domestic production.

Table 1 shows the demand and supply of crude steel production in the world. This is an indicator of the steel-making process. In Asia as a whole crude steel production has been increasing, but this has not been large enough to meet the

region's increasing demand for crude steel. There was a shortage of about 10 million tonnes in 2005. Up to 2004 Japan was the only country in Asia that was able to export crude steel; from 2005 China also became an exporter of crude steel. This supply-demand gap in crude steel production reflects the changing pattern in the international division of labor in steel production, which needs to be examined.

Table 1 Crude steel supply and demand by region

Million tonnes

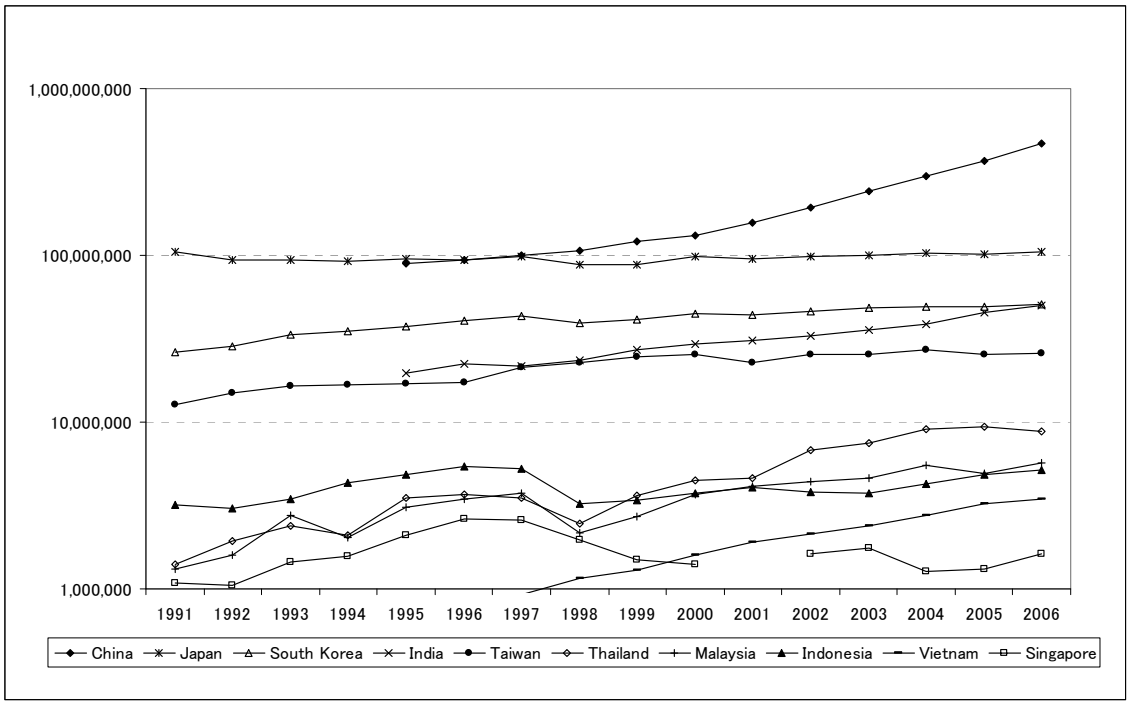
	Apparent consumption (A)			Production (B)			Balance (B - A)		
	1985	1995	2005	1985	1995	2005	1985	1995	2005
Japan	73.4	84.3	82.9	105.3	101.6	112.5	31.9	17.3	29.6
South Korea	11.3	37.3	49.0	13.5	36.8	47.8	2.2	-0.5	-1.2
Taiwan	6.3	24.1	23.9	5.2	11.6	18.9	-1.1	-12.5	-4.9
China	69.5	100.2	350.2	46.8	95.4	355.8	-22.7	-4.9	5.6
Indonesia	2.4	7.3	7.8	1.4	4.1	3.7	-1.0	-3.1	-4.1
Malaysia	2.0	8.3	7.3	0.4	2.5	5.3	-1.6	-5.8	-2.0
Thailand	1.9	11.9	15.3	0.4	2.1	5.2	-1.5	-9.8	-10.1
Philippines	0.7	4.7	2.9	0.3	0.9	0.5	-0.4	-3.8	-2.4
Singapore	2.0	5.0	3.4	0.4	0.5	0.6	-1.7	-4.5	-2.9
Vietnam	0.1	0.8	7.7	0.1	0.3	0.9	-0.1	-0.5	-6.8
Other Asia	14.4	26.1	41.3	11.9	22.0	38.1	-2.5	-4.1	-3.2
Total Asia (excluding Japan)	121.3	232.2	518.6	88.0	178.0	478.2	-33.3	-54.2	-40.5
Asia	194.7	316.5	601.5	193.3	279.6	590.6	-1.4	-36.9	-10.9
EU15	110.4	145.9	154.0	147.5	155.8	165.1	37.1	9.9	11.1
Other Europe	68.0	37.6	53.8	70.7	49.3	53.5	2.7	11.7	-0.3
USSR/Former USSR	157.3	33.4	52.7	154.7	79.1	113.4	-2.6	45.7	60.8
Middle East	15.3	14.5	36.8	2.7	8.1	15.3	-12.6	-6.4	-21.5
Africa	16.5	16.5	26.5	12.3	13.7	17.9	-4.2	-2.8	-8.6
NAFTA	124.7	135.2	153.7	102.1	121.8	126.4	-22.6	-13.5	-27.3
Central and South America	21.1	29.5	36.8	28.8	35.6	46.5	7.7	6.1	9.7
Oceania	6.6	7.3	8.7	6.8	9.3	8.6	0.2	2.0	-0.1
World	714.6	736.4	1,125.6	718.9	750.2	1,138.8	4.3	13.8	13.1

Source: IISI, *SSY* (various issues).

Figure 5 shows the trend in the production of hot-rolled products which indicates the rate of domestic production accounted for by the rolling process. A comparison of this trend with Figure 2 showing the trend of domestic demand indicates that the production rates of many countries show the same trends as their consumption trends. In China, India and Vietnam the production of hot-rolled products has increased considerably in comparison to the increase in steel demand. The production in South Korea and Thailand after the East Asian financial crisis exceeded the level achieved before the crisis, and that of Indonesia and the Philippines has not recovered to the pre-crisis level. In contrast, the production of hot-rolled products in Taiwan and Malaysia shows a different pattern from that of their consumption trend. While their domestic consumption has not recovered to the level achieved before the crisis, their production has exceeded the pre-crisis level.

Figure 5 Hot-rolled products (1991-2006)

(Tonnes)



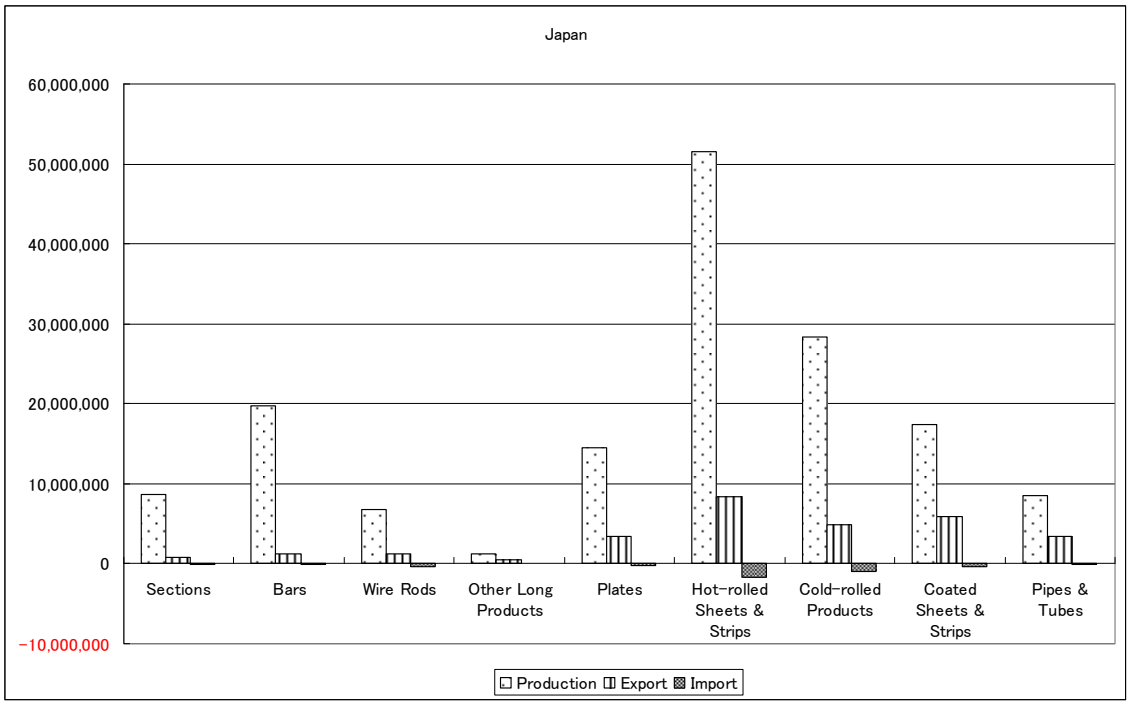
Source: For China and India, IISI, *SSY* (various issues). For the remaining countries, SEAISI, *SSY* (various issues).
Note: The data are plotted against the logarithmic scale.

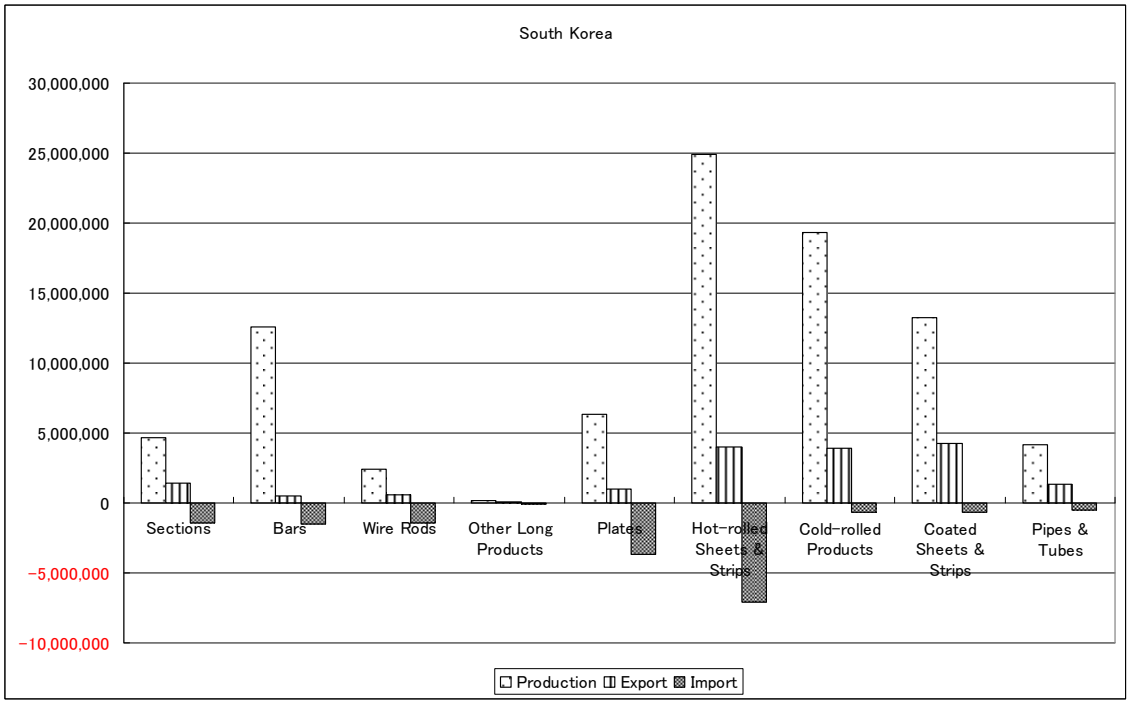
Figure 6 depicts the production and trade volume of each country by finished product. It should be noted, however, that unlike Figure 4 where the statistical duplication of flat products has been omitted in showing final demand for each product, this has not been done in Figure 6 as it is impossible to omit the duplication of imported flat products which are used for further processing in the steel industry; thus the domestic production rates shown in the figure include the products consumed within the steel industry for further processing, and also the products purchased by the other industries.

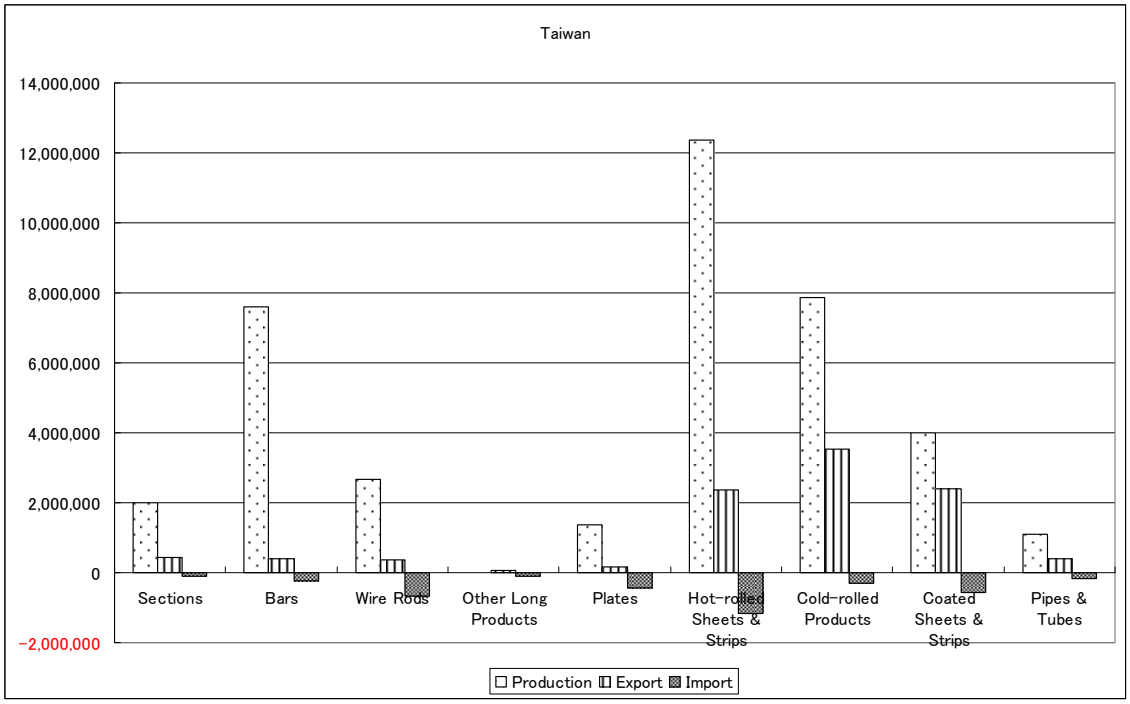
From Figure 6 it is immediately clear that the Southeast Asian countries (Thailand, Malaysia Indonesia, the Philippines and Vietnam) import considerably more flat products than they produce domestically, and for the Philippines and Vietnam, the production of hot-rolled sheet and coils is extremely low. The figure also indicates that the production and trade structure of South Korea and Taiwan looks similar, however, in South Korea the import of plates and hot-rolled sheets and coils is high while in Taiwan the export of cold-rolled sheets and coils and surface-treated products is important. Furthermore, in China and India the production of long products is quite large while a certain amount of flat products are imported.

Figure 6 Production and trade for Asian countries by finished product (2006)

(Tonnes)






Taiwan
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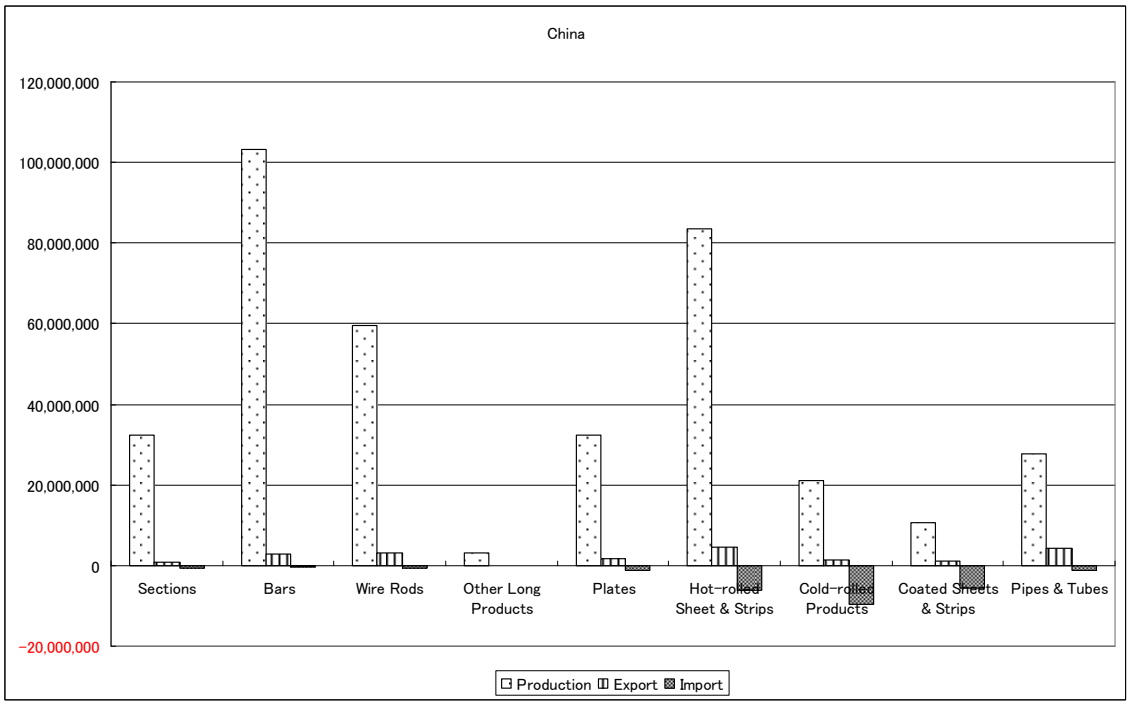
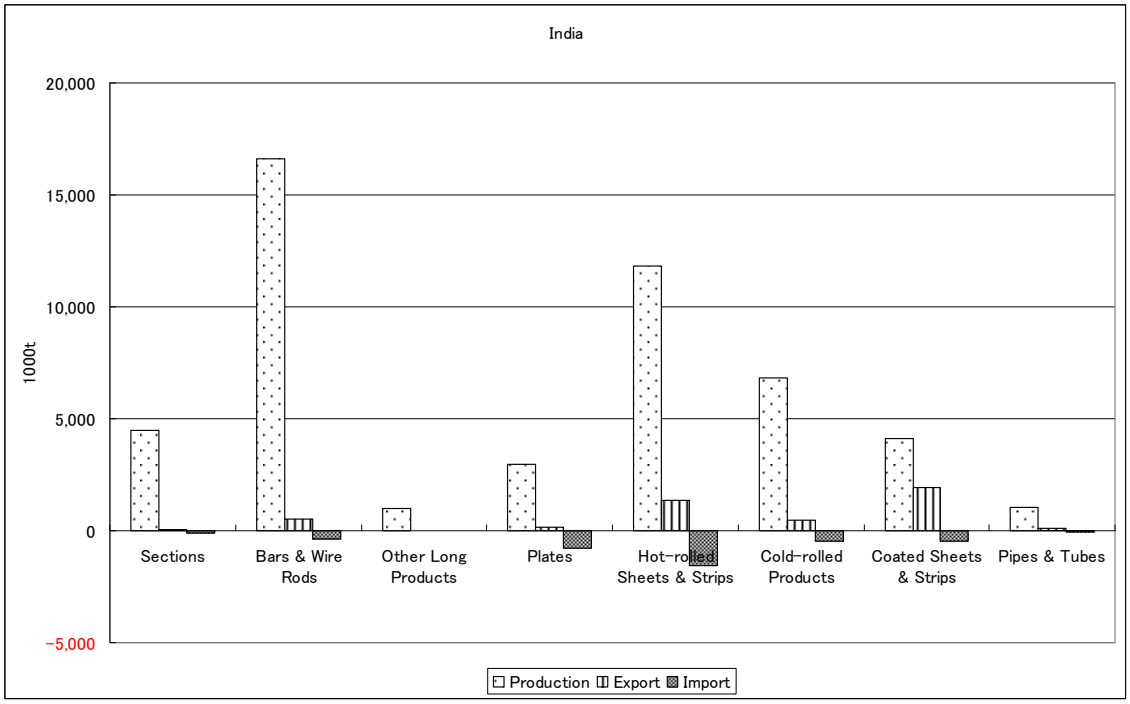
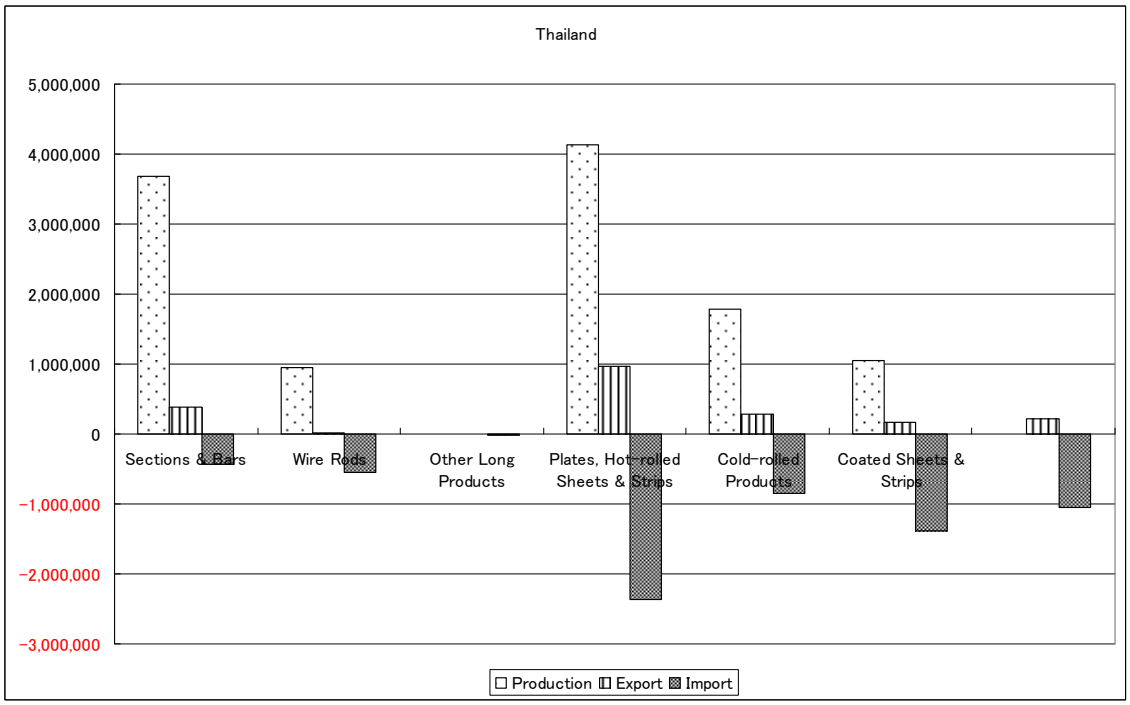
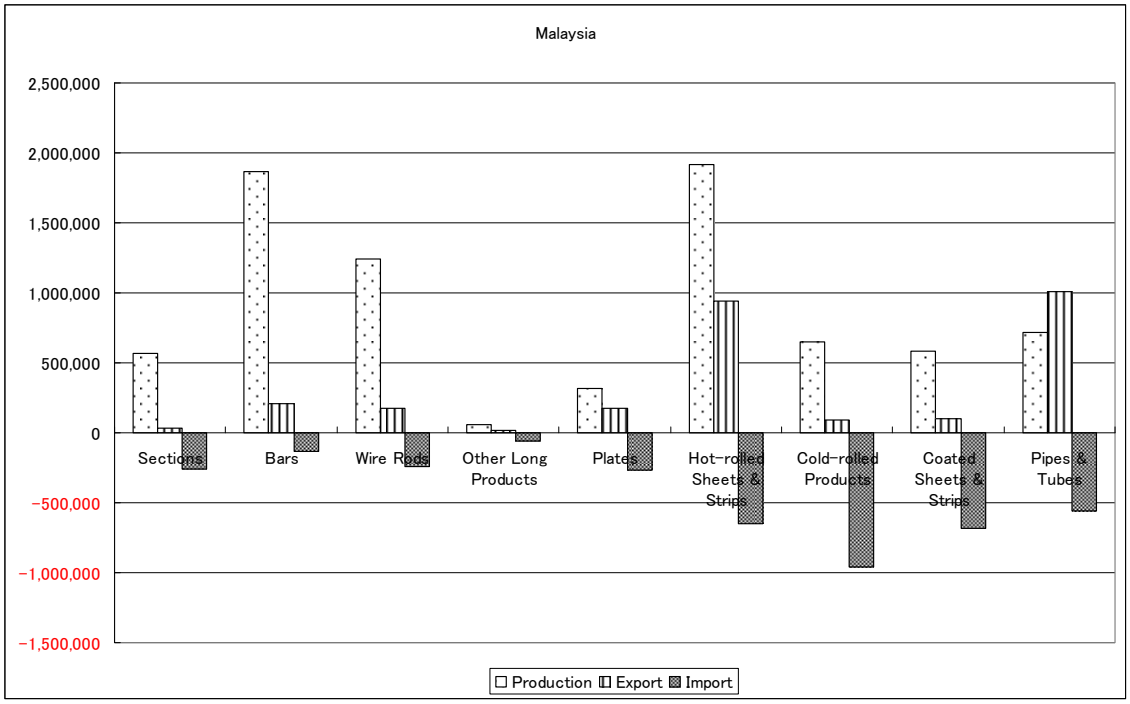
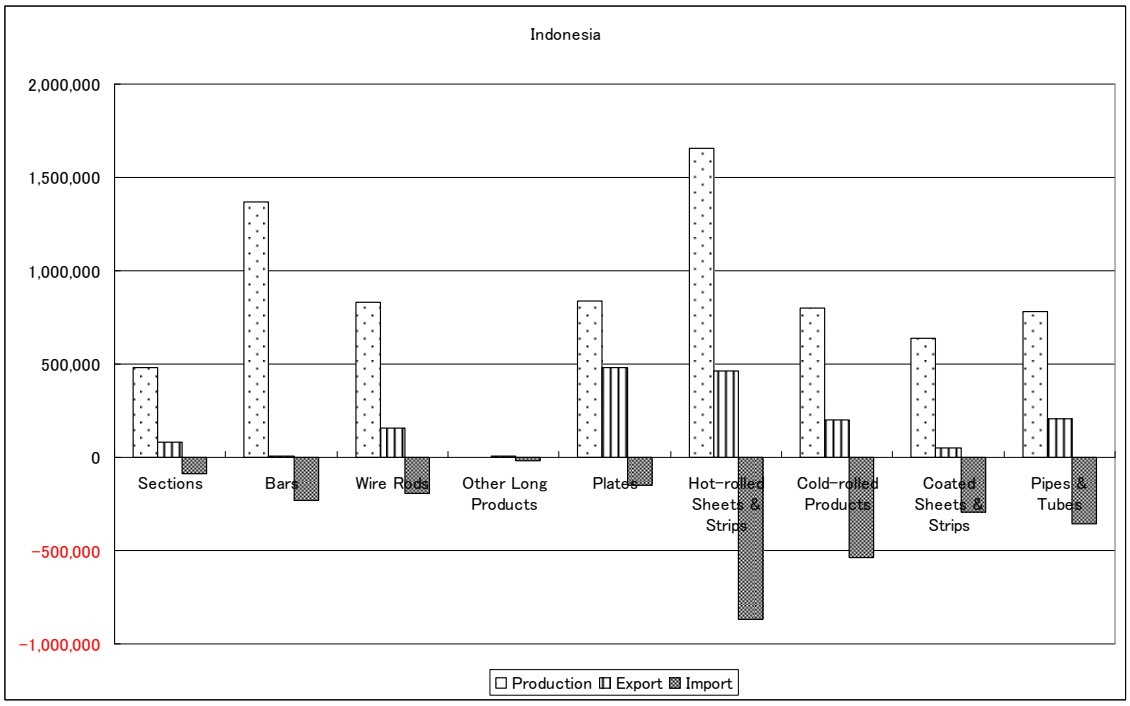
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
-2,000,000
Sections
Bars
Wire Rods
Other Long Products
Plates
Hot-rolled Sheets & Strips
Cold-rolled Products
Coated Sheets & Strips
Pipes & Tubes
Production
Export
Import

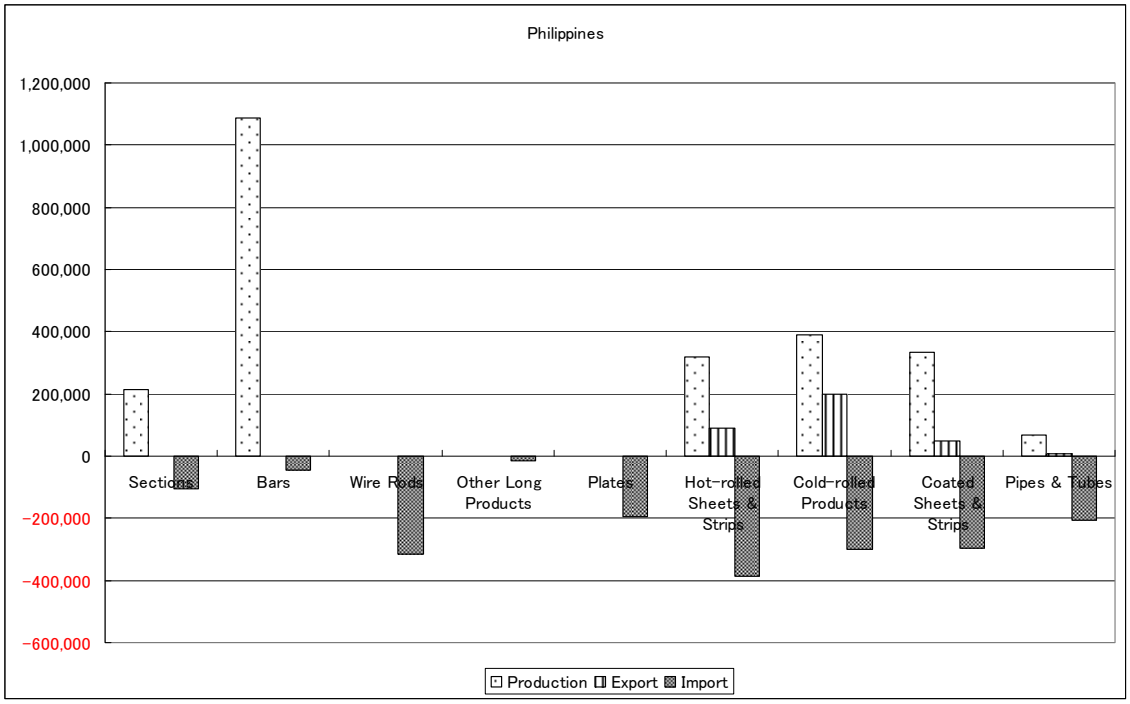

China
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
-20,000,000
Sections
Bars
Wire Rods
Other Long Products
Plates
Hot-rolled Sheet & Strips
Cold-rolled Products
Coated Sheets & Strips
Pipes & Tubes
Production
Export
Import

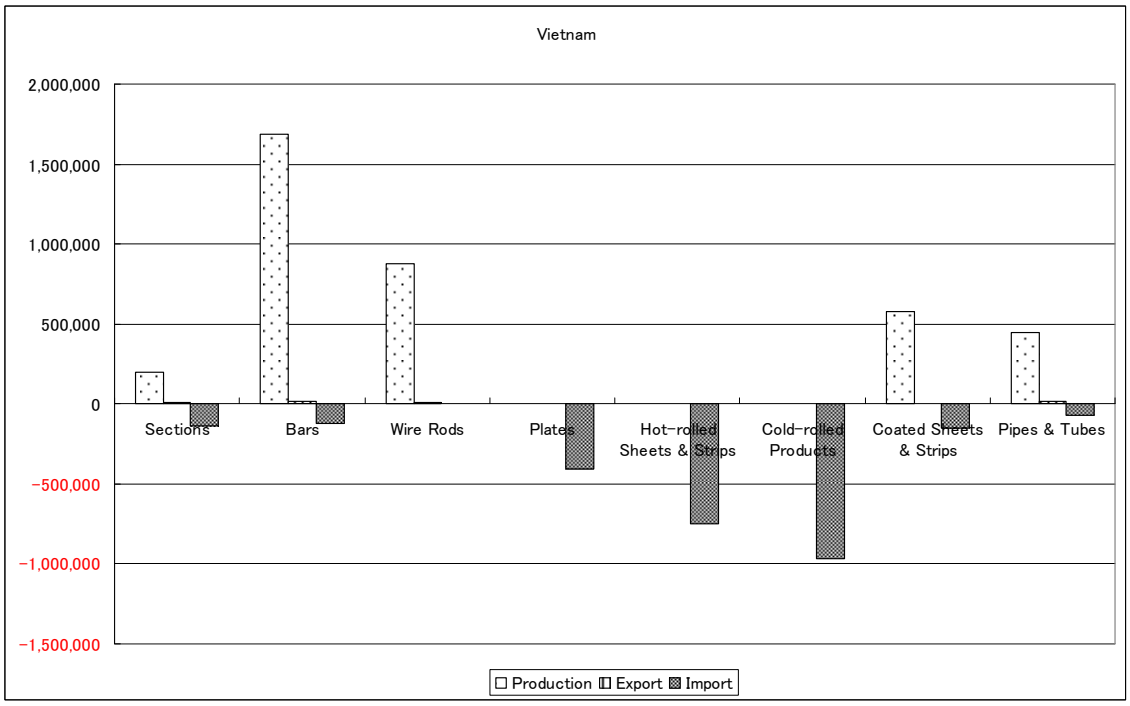

India
20,000
15,000
10,000
5,000
0
−5,000
1000t
Sections
Bars & Wire Rods
Other Long Products
Plates
Hot-rolled Sheets & Strips
Cold-rolled Products
Coated Sheets & Strips
Pipes & Tubes
Production
Export
Import


Thailand
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
−1,000,000
−2,000,000
−3,000,000
Sections & Bars
Wire Rods
Other Long Products
Plates, Hot-rolled Sheets & Strips
Cold-rolled Products
Coated Sheets & Strips
Production
Export
Import


Malaysia
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
-500,000
-1,000,000
-1,500,000
Sections
Bars
Wire Rods
Other Long Products
Plates
Hot-rolled Sheets & Strips
Cold-rolled Products
Coated Sheets & Strips
Pipes & Tubes
Production
Export
Import


Indonesia
2,000,000
1,500,000
1,000,000
500,000
0
-500,000
-1,000,000
Sections
Bars
Wire Rods
Other Long Products
Plates
Hot-rolled Sheets & Strips
Cold-rolled Products
Coated Sheets & Strips
Pipes & Tubes
Production
Export
Import





Source: SEAISI, *SSY* (2007) excluding China and India. For China, CISA, *SSY* (2006), for India, JPC, *mimeo*.
Note: For China 2005, for India fiscal year 2005, for Vietnam 2004.

3.5 Import structure for semi-finished and flat products in Asian countries

Tables 2, 3, 4 and 5 indicate the international division of labor in steel production. For semi-finished products such as billets and slabs, as shown in Table 1, the Southeast Asian countries are net importers of crude steel. Table 2 shows that

these countries depend on imports principally from China and Russia.

Table 2 Imports of semi-finished products (2006)

(%)

Thailand		Vietnam		Indonesia		Philippines		Malaysia	
Russia	41.0	China	77.8	Ukraine	36.3	Russia	57.3	China	90.6
China	35.4	Russia	4.9	China	34.5	China	22.2	Thailand	3.6
Brazil	8.6	Japan	3.8	Russia	18.2	India	14.9	Indonesia	2.8
Australia	4.4	Ukraine	3.3	India	4.3	Indonesia	3.0	Brazil	2.2
Malaysia	2.5	South Korea	3.2	Australia	1.6	Other Asia	1.1	Japan	0.7
World	100.0	World	100.0	World	100.0	World	100.0	World	100.0
(1,000 tonnes)	3924		1956		1918		789		422

Source: UN ComTrade.

Tables 3, 4 and 5 focus on the import structure for flat products. Hot-rolled flat products are used as inputs for cold-rolled products and surface-treated products and are used in other industries as well such as shipbuilding and automobiles. South Korea is the largest importer among the countries shown in Table 3. The imports of China, India and Thailand are larger than those of Japan and Taiwan. Except for Japan and South Korea, the average import price per kg of hot-rolled flat products is higher than the average export price, implying that higher value-added products are imported. For all of the countries except India, more than 80% of imports come from Asia; for India the figure is 40.6%.

Table 3 Imports of hot-rolled flat products (2006)

(%)

		Importers							
		Japan	South Korea	Taiwan	China	India	Thailand	Malaysia	Indonesia
Exporters	Japan	–	51.4	36.1	56.4	5.3	76.3	26.3	28.4
	South Korea	45.4	–	18.6	14.1	14.1	6.3	6.8	6.4
	Taiwan	37.4	1.8	–	11.9	1.0	1.7	34.3	15.7
	China	14.3	39.9	31.5	–	12.1	7.4	2.5	18.2
	India	0.0	0.1	0.9	0.1	–	0.3	0.5	11.7
	Thailand	0.0	0.1	0.9	0.4	0.6	–	1.5	4.0
	Malaysia	0.0	0.0	0.0	0.1	2.7	0.2	–	1.0
	Indonesia	0.6	0.2	0.0	0.0	3.2	0.0	5.0	–
	Philippines	0.0	0.3	0.0	0.0	1.8	0.0	0.0	0.0
	Vietnam	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
	Sub-total	97.7	93.8	88.0	83.1	40.6	92.3	77.0	85.4
	World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	(million US$)	892.6	5509.7	640.4	1460.4	1652.6	1166.6	472.7	385.4
Average Import Price		0.49	0.54	0.50	0.57	0.60	0.59	0.40	0.56
Export Price – Import Price		0.07	0.03	−0.04	−0.09	−0.03	−0.04	−0.11	−0.02

Source: World Trade Atlas.
Note: Average price is shown as US$/1kg.

Table 4 shows the import structure for cold-rolled flat products in the Asian countries. These products are further processed to become galvanized and tin plates and are used in the other industries as well such as electronics. The intra-trade in the products among the countries (sub-total) is much deeper than for hot-rolled flat products shown in Table 3. Most of the countries in the table depend on Japan,

South Korea and Taiwan. Even for India the share of imports from the Asian countries is 76.6%. Japan's share as a source of imports for Thailand is extremely high at 68.7%. China is the largest importer, and the Southeast Asian countries are larger importers than are South Korea and Taiwan. The average import price per kg is higher than the average export price for all the countries except Japan.

Table 4 Imports of cold-rolled products (2006)

(%)

		Importers							
		Japan	South Korea	Taiwan	China	India	Thailand	Malaysia	Indonesia
Exporters	Japan	–	44.1	53.7	28.7	14.1	68.7	31.6	48.9
	South Korea	77.4	–	33.8	25.5	52.2	13.7	17.7	19.0
	Taiwan	20.1	18.7	–	26.9	0.3	5.8	20.9	11.5
	China	0.3	21.1	6.2	–	4.8	2.1	3.8	5.6
	India	0.0	0.2	0.3	0.3	–	1.0	3.6	2.7
	Thailand	0.1	0.0	3.0	1.5	3.4	–	3.6	1.2
	Malaysia	0.0	0.0	0.0	0.1	1.1	1.2	–	1.6
	Indonesia	0.0	0.0	0.0	0.5	0.0	2.0	5.9	–
	Philippines	0.0	4.5	0.0	0.0	0.6	2.0	2.2	3.4
	Vietnam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sub-total	98.0	88.6	97.1	83.6	76.6	96.4	89.4	94.0
	World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	(million US$)	497.5	234.1	66.5	2321.1	249.2	435.3	416.3	280.8
Average Import Price		0.55	0.61	0.72	0.59	0.68	0.72	0.63	0.64
Export Price – Import Price		0.09	−0.01	−0.15	−0.05	−0.04	−0.15	−0.29	−0.07

Source: World Trade Atlas.
Note: Average price is shown as US$/1kg.

Table 5 shows the import structure of surface-treated flat products. These are basically used for high value-added products such as cans and automobiles, although it should be noted that galvanized plates are also used for low value-added products such as roofing. The Asian countries, again with the exception of India, import more than 80% of these products from the Asia region; and Japan and South Korea are again the major sources for the imports of the Southeast Asian countries.

Table 5 Imports of coated products (2006)

(%)

		Importers							
		Japan	South Korea	Taiwan	China	India	Thailand	Malaysia	Indonesia
Exporters	Japan	–	71.4	59.5	47.8	25.2	66.5	53.8	34.0
	South Korea	79.9	–	12.6	24.9	25.5	20.3	22.1	26.5
	Taiwan	9.7	1.6	–	18.7	2.9	3.9	10.8	8.4
	China	4.0	18.8	19.3	–	1.6	3.6	5.5	5.7
	India	0.1	0.1	0.8	0.2	–	0.5	0.9	0.4
	Thailand	0.0	0.0	0.0	0.3	4.8	–	1.2	1.2
	Malaysia	0.0	0.0	0.3	0.3	1.5	0.8	–	3.3
	Indonesia	0.0	0.0	0.0	0.0	0.7	0.3	0.2	–
	Philippines	0.0	0.0	0.0	0.0	0.0	0.3	0.2	2.0
	Vietnam	0.0	0.0	1.1	0.0	0.1	0.1	3.2	1.1
	Sub-total	93.7	92.0	93.7	92.2	62.2	96.3	97.8	82.7
	World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	(million US$)	299.6	494.5	405.9	3438.6	299.8	1159.8	502.9	227.7
Average Import Price		0.70	0.89	0.70	0.75	0.83	0.87	0.50	0.83
Export Price – Import Price		0.07	−0.10	0.07	−0.04	−0.03	−0.01	−0.42	0.04

Source: World Trade Atlas.
Note: Average price is shown as US$/1kg.

The foregoing series of tables highlight the international trade networks in flat products within the Asian region. It can also be seen that China is an important source for Asian country imports of semi-finished products while Japan, South Korea and Taiwan appear to be important sources for finished products. This indicates that there is an international division of labor in steel production. Therefore, the segments of domestic steel markets which are supplied by imports should also be examined in addition to the segments supplied by domestic production. Important questions are how the divisions of labor in the markets have formed, whether import substitution in a market segment is progressing, and what types of firms supply what market segments.

4. Findings of the Study

The foregoing sections have discussed the basic features of steel production technology and firm types as well as of the steel industries in Asian countries. In doing so, they touched upon issues examined in each county study which will now be summarized.

This section presents the essence of the case studies on the steel industries in the Asian countries examined, namely, South Korea, Taiwan, China, India, Indonesia, Thailand and Malaysia.[11] It will then offer a brief discussion on the development and restructuring of the steel industry in Asia based on the findings of the case studies.

4.1 Summary of country studies

South Korea

The South Korean steel industry developed rapidly following the establishment of POSCO, a state-owned integrated firm, in the early 1970s. However, it has gone through significant changes, particularly since the East Asian financial crisis in 1997. Even before the crisis, fierce investment competition in the industry had been taking place since the early 1990s. This competition was triggered principally by the deregulation of entry restrictions in the late 1980s. As a result, steel firms aggressively entered into the various downstream sectors such as cold rolling. This created an imbalance among the processes of the industry which widened through the 1990s. In the post-crisis restructuring, this imbalance along

[11] See Abe (2008) for South Korea, Yukihito Sato (2008) for Taiwan, Sugimoto (2008) for China, Ishigami (2008) for India, Yuri Sato (2008) for Indonesia, Kawabata (2008) for Thailand, and Hajime Sato (2008b) for Malaysia, for detailed discussion.

with the conflict of interests between privatized POSCO and the Hyundai Motor group have been major factors driving the reorganization of the industry. In sum, the South Korean experience is an example of the transformation of the steel industry from state-led development to liberalization and privatization through competition among private firms.

Taiwan

In contrast to Japan and South Korea, Taiwan has no major steel-using industries such as automobiles and shipbuilding. Nevertheless, the Taiwanese steel industry successfully introduced integrated steel production in the late 1970s with the establishment of CNC, a former state-owned steel firm. Thereafter the development of the industry was driven mainly by demand for flat products, particularly cold-rolled and galvanized products that have been exported to mainland China since the 1990s, and color steel products exported to the USA. Indeed, the development of the industry has been characterized by export-oriented development to a significant extent, at least for the flat-steel sector. As Taiwan's flat-steel production developed, CNC moved into the different levels of the rolling process while a number of pipe and tube makers invested in the upstream processes of rolling. This has led to the privatized CNC now operating as both a provider for and competitor of other domestic rolling firms, and this structure has become a bottleneck in the upgrading of product quality. CNC is endeavoring to produce high-grade steel in association with the metal and machinery industries. In sum, the development experience of the Taiwanese steel industry shows a unique pattern that has had no strong support from a steel-using industry such as automobiles.

China

China has experienced explosive growth in both steel demand and production. Private firms and middle-sized state-owned firms have played an important role in the country's impressive development since the late 1990s through their quick response to the increase in steel demand. The growth of domestic steel production has led to changes in the steel trade. Import substitution has proceeded; imports are increasingly limited to high value-added products, and China has become an important provider of semi-finished products (billets) to ASEAN countries. Also hot-rolled coils for ordinary usage have been exported to South Korea since the 1990s, where the imbalance among the steel industry's processes has necessitated imports. Regarding raw materials, imports as well as the domestic supply of coal and iron ore have been increasing dramatically with the growth of

steel production. Underlie the rapid development of the industry has been the diversification of China's sources of finance for facility investment and enhanced management autonomy, both of which reflect changes in government policy. Added to these are the backward linkages from the manufacturing sector and the civil engineering and construction sector that have been growing rapidly at least since the mid-1990s.

India

Since the start of economic liberalization in 1991, the structure of the Indian steel industry has undergone significant reorganization. Before liberalization the state-owned firm SAIL had played the core role in steel industry development. Since liberalization a triple structure of main, secondary and small-scale producers has appeared. Amongst the main producers consisting of incumbent integrated firms, technological upgrading and institutional reform have been slow for SAIL, while Tata Steel has gradually upgraded its facilities as well as the quality of its products. Secondary producers Essar, Ispat and Jindal have introduced newly available technology such as DRI and CC and are endeavoring to make efficient use of domestically available raw materials. It is this sector that has principally contributed to the rapid growth of the industry since liberalization. Also they are more export oriented than SAIL. Small-scale producers depend on induction furnaces which are considerably small-scale technology and utilize scrap steel. India's steel market is segmented geographically and in product quality, and this has enabled small-scale producers to grow. The post-liberalization experience of the industry presents a unique example where newcomers have sought to utilize locally available raw materials with new technology.

Indonesia

The Indonesian steel industry does not have a mass production system with mammoth blast furnaces, but does undertake integrated steel production using DRI. This integrated steel production is burdened by the inefficient state-owned firm Krakatau Steel, and the industry as a whole suffers a significant imbalance among production processes in terms of capacity, especially in the flat-steel sector. Steel demand for flat products has been largely met by imports, due to the stagnant growth of domestic production. The stagnation of the industry has been due to the low demand for steel because of the country's low economic growth, dependence on imported raw materials, and the market penetration of imported steel products. The uncompetitiveness of Krakatau Steel against imported steel products can be

attributed to such factors as long-lasting protective measures, chronic deficits, lowered cost advantages due to the rising price of natural gas, and the negative historical legacy of its location and facilities. There is a possibility that the growth of the industry will pick up as steel demand increases. However, in this era of trade liberalization and burdened by a production structure centered on Krakatau Steel, Indonesia's steel industry is suffering many problems that will not be easy to overcome.

Thailand

Since the East Asian financial crisis, demand for flat-steel products, particularly high-grade products, has been growing rapidly in Thailand. Historically, the development of the Thai steel industry began from the rolling process. There has been no state-owned firm, and overseas Chinese firms have played the major role. In other words, through the 1990s it was private firms that entered the downstream processes and gradually substituted domestic products for imports. However, import substitution faced difficulties in hot-rolled coils and sheets because of the capital and technology required. Moreover, the financial crisis put a brake on major local firms and projects in the flat-steel sector. In the course of restructuring in this sector, the cold rolling process has been taken over by foreign firms and local firms only survived in the hot rolling process. As the country's export-oriented automobile industry developed, the Thai steel market grew both in terms of volume and quality especially after the crisis. However, local firms now face difficulties in responding to the shift in demand from low- to high-grade steel. They must also compete against the strengthened international networks of foreign integrated steel firms that provide mother products to their affiliated firms in Thailand. There are also the managerial limitations of family-based business. The Thai steel industry offers an interesting case of having no state-owned firm and development based entirely on private firms.

Malaysia

The development of the Malaysian steel industry can be divided into three stages. First came Malayawata Steel, a state-owned firm established in the late 1960s. This was an integrated steelworks with small blast furnaces that contributed to the import substitution of long steel products. Next was Perwaja Trennganu, a state-owned firm established in the mid-1980s that utilized DRI furnaces and EAFs. It relied on domestically available natural gas, but this project turned out to be a failure technologically. In the late 1980s, as the economy grew mainly due to the

rapid growth of the electronics industry, demand for flat products increased. In response to this and to Malaysia's liberalization policy towards FDI, rolling firms, mainly foreign owned, entered into the rolling process of the flat-steel sector. These developments brought the third step in the country's steel industry, the establishment of a domestic private firm, MegaSteel, to produce substitutes for imports of hot-rolled coils and slabs. As in the case of Thailand, this project is facing difficulties in terms of technology and the strengthened networks of foreign integrated firms. The experience of the Malaysian steel industry shows that while the government and firms sought to utilize domestically available raw materials, such as natural gas, with new technology, they had to do so under conditions of small domestic demand and limited financial sources.

4.2 Conclusion

From the summaries of the country studies above, it is clear that the development of the steel industry in Asia cannot easily be understood by the dichotomy of state-led or market-led. Rather, the diversity of the development process is more important, as the conditions under which the steel industry in each country operates differ across time and countries.

Production technology

Several points can be drawn regarding technology. First, the endowment of raw materials does affect the choice of technology and firm type, often through industrial policy; however, there can be change as ideology and economic policy shift. China and India, for example, with their iron ore and coal mines, historically followed the strategy of building steel plants inland close to the raw materials. This affected their industrial structure. Recently however, the new plants in these two countries have been built in coastal areas for better access to markets as well as to imported raw materials. Countries like South Korea and Taiwan without raw materials built their integrated steelworks from the very start at deep water ports. China now has a policy of scrapping inefficient and obsolete steel production facilities, and seems to be concentrating steel production on the second generation model of integrated steel production. In contrast, India has been introducing various new technological models and installing new technology that uses natural gas and low-grade coal as inputs. Many steel mills in Indonesia and Malaysia operate on domestically available natural gas.

Second, local firms have faced difficulties in choosing technology and targeting markets, especially for the flat-steel sector where product demand is

covering an increasingly wide range of steel grades. The BOF method with mammoth blast furnaces can produce various steel products from high to low grade; however, with the EAF method, it is difficult to produce high-grade flat products. In Thailand, Malaysia and Indonesia, no local firms have fully succeeded in producing hot-rolled flat products for high-grade usage. Another interesting finding is the case of Taiwan. The increase in the production of flat-steel products, especially high value-added products, has typically been associated with the growth of the automobile industry, as with Japan and South Korea. However, the development of the Taiwanese steel industry followed a different path, one that relied on exporting.

A third point and one reflecting trade and financial liberalization, the international division of labor in steel production processes, including those for flat products, has been progressing. In Southeast Asian countries where there is no integrated steel production with large blast furnaces, FDI from integrated steel firms in Japan, South Korea and Taiwan can be seen in the rolling sector such as cold rolling and surface treatment. These rolling firms import mother products from their parent integrated firms. The international networks for the high value-added flat products of integrated firms in advance countries have existed at least since the late 1980s, and it seems that these have been significantly strengthened since the East Asian financial crisis.

The production technology in the steel industry is basically a matured one. Therefore important for development of the industry in latecomer countries is learning the technology they choose to introduce. The initial investment and minimum-efficient scale differ significantly across technologies. Thus the crucial issues for latecomers are which technology to choose and when to introduce it given the shifting conditions of demand and factors such as a country's infrastructure and access to finance,. Therefore, additional factor inputs are important for latecomer steel industry development, and technological innovation is a task for the far future. As shown by the experience of the Southeast Asian countries, it is difficult even now for local firms to introduce and successfully operate the technology for producing hot-rolled flat products (slabs and hot-rolled coils). In contrast, the steel industries in South Korea and Taiwan have moved beyond learning and absorbing technology, and technological innovation is becoming an important task. Indeed, these countries are making significant efforts to upgrade steel products and their technologies.

The role of the state

The designation of the steel industry as a strategic national industry and state-led development of the industry has been common for the countries in this

study, with the exception of Thailand. However, this state-led development is in apparent decline, although the processes have been different for each country. For South Korea (POSCO), Taiwan (CNC), and Malaysia (Malayawata and Perwaja), the state-owned firms that played the core role in the development of the steel industries in these countries have been privatized, and this privatization in turn has brought about changes in the vertical integration or vertical division of labor within the industry. In India the presence of the state-owned firm (SAIL) has been significantly lessened since economic liberalization, relative to the newly entered private firms. The state-owned firm in Indonesia (Krakatau) is faced with problems of weak management and competition from imports. In China since the explosive growth of steel production in the late 1990s, private firms have played an important role. In short, even in the nationally important steel industry there has been a downward trend, especially since the 1990s, in state-led development through direct government involvement and state-owned firms.

The case studies also show that the impact of industrial policy has been different across countries and time. Coordinating the development of the steel producing industry with the steel consuming industries turned out to be extremely difficult. With the exception of South Korea in the 1970s and 1980s, countries such as Taiwan, India, Indonesia and Malaysia which attempted such planned coordinated development were unable to realize this aim. However, regardless of the success or failure of these attempts, industrial policy affected the development of each country's steel industry. In South Korea, for example, policy regulating the entry of firms into the industry and change to this policy set the basic conditions of the industry's structure with its imbalance among steel processes that persists to the present day. Even in Thailand policy regulating firm entry and change thereto were aimed at promoting import substitution by local firms in the hot-rolling flat-steel sector. Likewise the national liberalization policies to encourage FDI have greatly affected the industrial structure and division of labor among local and foreign firms in Asia. Even the protectionist measures that continue in some countries such as Malaysia are bringing further restructuring of the flat-steel sector in those countries.

In sum, in South Korea, Taiwan, India and China, the role of state was critical to introducing integrated steelworks. Also in Indonesia and Malaysia up to the 1980s, the introduction of upstream processes (DRI) had to rely on state projects. From the 1990s, however, as countries experienced rapid economic development and growing steel demand along with financial and investment liberalization, development of the steel industry centered on state-own firms became less apparent.

Nevertheless, there are still many areas, such as infrastructure provision, demand creation, FDI regulation, mergers and competition, and FTA arrangements, where state policy greatly affects the development and restructuring of the steel industry. And environmental policy is now becoming much more important.

Demand

The case studies highlighted two important points regarding demand. One is which linkage, backward or forward, has been more important for the development of the steel industry. In Southeast Asia the development of the industry has been characterized by the backward linkage from the growth of the export-oriented steel-using industries that developed rapidly in the region. In these countries the steel industries themselves are not export-oriented. However, export-oriented national policy and the liberalization of FDI triggered the growth in export-oriented industries such as electronics, and this pushed the growth of the overall economy which also stimulated steel demand. This increase in demand has enabled the region's domestic steel industries to gradually move into import substitution. South Korea's steel industry, on the other hand, arose in the 1970s and followed a very different course. Given the size of the minimum-efficient scale of an integrated steelworks, Korea had to depend right from the start not only on its small domestic demand but also on foreign demand if it was to enjoy the scale economies of full operation. Moreover, the introduction of integrated steelworks enabled the steel-using industries such as shipbuilding to grow by forward linkage which in turn contributed to the growth of steel demand. From the mid-1980s, however, the growth of the country's steel industry was induced largely by the backward linkage of the rapidly growing export-oriented steel-using industries which increased domestic steel demand. In Taiwan's case, the steel industry, especially since the 1990s, has grown through increasing exports and depends directly on foreign demand especially from China and the USA. In China and India where the domestic markets are geographically large and segmented and where steel production started by utilizing domestically available natural resources, the industry depends upon domestic demand, although in recent years exports have become more important for these two countries as well.

The second point is that the size of domestic demand and its stratification, and the process of stratification appear to be crucial for the industry's development. Countries with domestic demand over 20 million tonnes, i.e., China, South Korea, India and Taiwan, have been able to absorb a variety of technologies ranging from integrated steel production with mammoth blast furnaces to small bar mills. In

contrast, countries with domestic demand of less than 20 million tonnes are having difficulty trying to introduce certain technologies, especially for hot-rolled flat products. To produce high-grade flat products, quality control must to be integrated with upstream processes (iron and steel making) which the steel industries in the smaller Asian economies are finding difficult to do. As a result, the foreign integrated firms with their international division of labor rely on the import of mother products (slabs, hot-rolled coils) for their affiliated rolling firms (FDI). Moreover, the timing of the stratification of steel demand itself is important. The size of steel demand in Thailand in the mid-2000s reached the level of South Korea's in the 1980s, and that of Indonesia and Malaysia rose to that of Taiwan's in the 1980s (Figure 2). However, domestic demand for high-grade steel in the Southeast Asian countries rose while their steel industries were still in the early stage of development, and they were unable to supply this demand. Thus, the later the development of the industry, the higher the barrier posed by the international division of labor established by the integrated firms of the advanced countries. In other words, even when the size of demand reaches the level of minimum-efficient scale for technologies such as integrated steelworks and hot-strip mills, FDI in the steel-using industries has already heightened the stratification of steel demand in the countries where the domestic steel industry is still in its early stage. Thus local firms face difficulties in competing with imports and foreign firms in the high-grade steel sector.

Issues needing to be addressed

Some issues that this study did not address sufficiently include that of R&D and technology absorption. Sugimoto (2008) points out that technological development in integrated steel production has five aspects: (1) sector technology that promotes the efficient operation of each process, (2) facility technology that seeks to enhance the productivity of each facility of each process, (3) quality control technology that guarantees the quality of products, (4) production technology that minimizes production costs, and (5) R&D that develops new products or new methods. The absorption or innovation of technological development has been touched upon in this article, but detailed study is needed.

Another issue is environment problems. The steel industry is one of the largest energy consuming sectors, and as such, promoting energy efficiency and recycling has become an important task, especially for the industry in advanced countries. Thus environmental regulations, such as for reducing CO^2 emission, increasingly affect the technological choices and the pattern of development of the

steel industry. For example, integrated firms have been enhancing the ratio of scrap to pig iron used in the steel-making process in order to reduce CO^2 emission, and this has affected the supply and demand of scrap metal and the EAF sector. Another example is China which, for reasons of environmental pollution, imposed an export tax on steel products, and this has changed the structure of trade in steel products.

A third issue is M&A and other international restructuring involving technological transfer within a group of steel firms. As noted earlier, Mittal Steel bought Arcelor in 2006, and in 2007 Tata Steel acquired Corus. In Japan the five integrated steel firms reorganized themselves into two groups in 2002. Mittal, which seemed to target the low- and middle-grade long products of the world, now is aiming at the high-grade flat-steel market with its acquisition of Arcelor. In 2003 Tata Steel bought NatSteel of Singapore. This along with its later acquisition of Corus has given Tata a foothold in Southeast Asia and Europe in addition to India. Along with these regroupings, international business tie-ups or capital tie-ups appear to be increasing, such as that between NJS and POSCO, and between Sumitomo and CNC. Kawabata (2005) categorizes these international tie-ups into four types according to purpose: (1) technological transfer or exchange, (2) provision of mother produces, (3) stabilizing markets, (4) a mixture of the first three aims. These international tie-ups and the firms participating in them need to be studied, particularly for the effects of the global economic crisis of 2008.

References

Abe, M. (2008). "Kankoku Tekkōgyō no Sangyō Saihen: Sangyō Seisaku no Tenkan to Kiketsu" (Industrial Organization of the South Korean Steel Industry: Consequences of the Transformation of Industrial Policy) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 47-82.

Amsden, A. (1989). *Asia's Next Giant*. New York: Oxford Press.

D'Costa, A. P. (1999). *The Global Restructuring of the Steel industry: Innovations, Institutions and Industrial Change*. London: Routledge.

Ishigami, E. (2008). "Indo Tekkōgyō no Hatten to Henyō: Senpatsu Ikkan Mēkā, Shinkō Ōte Mēkā oyobi Shōkibobumon Teiritsu no Kōzu" (Development and Restructuring of the Indian Steel Industry: The Triple Structure of Main Producers, Secondary Producers and Small Scale Producers) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian:*

Development and Restructuring)(Ed, Sato, H.). Chiba: Institute of Developing Economies,pp. 159-202.

Kawabata, N. (2005). *Higashi Ajia Tekkōgyō no Kōzō to Dainamisumu (Structure and Dynamism of the Iron and Steel Industry in East Asia)* (in Japanese). Kyoto: Mineruva Shobō.

Kawabata, N. (2007). "Higashi Ajia niokeru Tekkō Kigyō no Seisan Shisutemu to Tōshi Kōdō" (Production System and Investment Behavior of Steel Firms in East Asia) (in Japanese). *Kinzoku* 77 (11), pp. 4-8.

Kawabata, N. (2008). "Tai no Tekkōgyō: Jiba Netsuen Kigyō no Chōsen to Kaisōteki Kigyōkan Bungyō no Keisei" (The Thai Steel Industry: Domestic Hot Rolling Companies under the Hierarchical Division of Labor) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 251-296.

Krugman, P. (1994). The Myth of Asia's Miracle. *Foreign Affairs* 73, pp. 62-78.

Okamoto, H. (1984) *Gendai Tekkōgyō no Ruikei Bunseki (Type-based Analysis of the Contemporary Steel Industry)* (in Japanese). Kyoto: Mineruva Shobō.

Pack, H. and Page, J. M. (1994). Accumulation, Exports and Growth in the High Performing Asian Economies. *Carnegie-Rochester Conference Series on Public Policy* 40, pp. 199-236.

Sato, H. (Ed.) (2008a). *Ajia Shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asia: Development and Restructuring)* (in Japanese). Chiba: Ajia Keizai Kenkyūsho (Institute of Developing Economies).

Sato, H. (2008b). "Malēshia no Tekkōgyō: Dankaitekina Yunyū Daitai no Shinkō to sono Konnan wo Megutte" (The Malaysian Steel Industry: The Gradual Progress and Difficulties of Import Substitution) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hattenn to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 297-343.

Sato, Yukihito (2008). "Taiwan Tekkōgyō no Seichō oyobi Kōdoka no Mekanizumu: Jidōsha Sangyō ni Izonshinai Hatten no Purosesu to Kanōsei" (Mechanism of the Growth and Upgrading of the Taiwanese Steel Industry: Could It Develop without Strong Support from the Automobile Industry) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 83-112.

Sato, Yuri (2008). "Indonesia no Tekkōgyō: Kiro ni Tatsu Kokuei Kigyō Shudō no

Ikkan Seisan Taisei" (Indonesia's Steel Industry: The State-led Integrated Steel Production System at a Crossroads) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 203-250.

Shin, J-S. (1996). *The Economics of the Latecomers: Catching-up, Technology Transfer and Institutions in Germany, Japan and South Korea*. London: Routledge.

Sugimoto, T. (2007). "Tekkōgyō no Gijyutu Kakushin" (Technological Innovation in the Steel Industry) (in Japanese). In *Ajia niokeru Tekkōgyō no Hatten to Henyō (Development and Transformation of the Steel Industry in Asia)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 23-66.

Sugimoto, T. (2008). "Chūgoku no Tekkōgyō: Bakuhatsuteki Kakudai no Shosokumen" (China's Steel Industry: Aspects of Its Explosive Growth) (in Japanese). In *Ajia-shokoku no Tekkōgyō: Hatten to Henyō (The Steel Industry in Asian: Development and Restructuring)*(Ed, Sato, H.). Chiba: Institute of Developing Economies, pp. 113-158.

Toda, H. (1984). *Gendai Sekai Tekkōgyō Ron (A Study of the Contemporary World Steel Industry)* (in Japanese), Tokyo: Bunshindō.

World Bank (1993). The East Asian Miracle: Economic Growth and Public Policy. Oxford: Oxford University Press.