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EXCHANGE RATES AND TRADE BALANCE ADJUSTMENT:  
THE CASE OF TAIWAN

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE  
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REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

ECONOMICS

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By

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Alvin Yiu Cheong So

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TO MY PARENTS

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## ABSTRACT

This dissertation explores the effect of exchange rate changes on the trade balance of Taiwan. It has two objectives. The first is to present a basic conceptual framework of trade adjustment to model Taiwan's trade flows. Development of the model draws on literature that examines the sensitivity of trade flows to changes in exchange rates. The second objective is to evaluate empirically the responsiveness to exchange rate fluctuations of Taiwan's trade imbalances with the United States and Japan.

A partial equilibrium empirical trade adjustment model that explicitly regarded the supply effect of changes in import prices on the export market was presented. This was done to reflect the fact that Taiwan has few natural resources and relies to a large extent on imported raw materials, energy, and other intermediate inputs for its production. The challenge is to estimate both the structural and reduced-form specifications by applying the methods of modern time-series econometrics to analyze the long-run trade balance adjustment and its relation to short-run dynamics.

The estimates generally support a role for exchange rate policy as a tool to reduce Taiwan's trade imbalance. Taiwan's exports and imports appear to be sensitive to changes in exchange rates and Taiwan's currency depreciation is found to have a positive effect on the trade balance. These findings are consistent with the traditional findings of international trade economists which have been challenged by recent studies. However, in the short run, the J-curve effect may exist, suggesting that Taiwan's exports and imports are insensitive to changes in exchange rates and a depreciation in Taiwan's currency is likely to have an initial perverse effect on the trade balance in the short run. The responsiveness of Taiwan and Japan trade to exchange rate changes appears to be smaller than that of Taiwan and the United States trade. The supply effect of import prices on Taiwan's exports does

not dominate the effect of an exchange rate change on the trade balance in the long run, but appears to have some impact in the short run.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Dissertation Objectives

This dissertation explores the effect of exchange rate changes on the trade balance of Taiwan. It has two objectives. The first is to present a basic conceptual framework of trade adjustment to model Taiwan's trade flows. Development of the model draws on literature that examines the sensitivity of trade flows to changes in exchange rates. The second objective is to evaluate empirically the responsiveness to exchange rate fluctuations of Taiwan's trade imbalances with the United States and Japan.

A substantial number of empirical studies have examined the responsiveness of trade flows to changes in the exchange rate. Many of these are cited in literature surveys of trade adjustment by Houthakker and Magee (1969), Leamer and Stern (1970), Magee (1975), Stern et al. (1976), Artus and Knight (1984), Goldstein and Khan (1985), and Hooper and Marquez (1993). In this study, the theoretical and empirical literature based on the elasticity approach are surveyed and used to establish an empirical model of Taiwan's trade balance adjustment.

Economists and policymakers have traditionally believed that a country can improve its trade balance by devaluing its currency. Yet, in the late 1980s, a currency depreciation coexisted with a trade deficit deterioration in the U.S. on one hand, and on the other hand, a currency appreciation has been accompanied by an increase in the trade surpluses of Germany, Japan, Korea, and Taiwan. Moreover, a series of empirical studies completed by Rose and Yellen (1989) and Rose (1990 and 1991) has cast some doubt on the traditional view. Using a time-series method that was progressively developed over the past decade, these authors were not able to detect any significant relationship between exchange rates and trade balances for both developed and developing countries. This study

employs the methods of modern time-series econometrics to study Taiwan's adjustment experience.

Over the past two decades, Taiwan has had record trade imbalances in both its multilateral and bilateral trade. In terms of multilateral trade, Taiwan has had a huge trade surplus since 1981. From the bilateral trade perspective, Taiwan has had huge trade surpluses with its largest export market, the United States, and sizable trade deficits with its largest importer country, Japan.

Taiwan is similar to Japan in that both economies have few natural resources, and are heavily dependent on imported raw materials, energy, and other intermediate inputs for producing export goods.<sup>1</sup> Figure 1 demonstrates that the export and import prices of Taiwan are closely related; they roughly move upward or downward together. Consequently, this dissertation differs from previous trade adjustment studies by assuming that the quantity of export supply is not only determined by export prices, but is also determined by import prices. I establish a partial equilibrium, empirical trade adjustment model for Taiwan that explicitly considers the supply shock effect of changes in import prices on the export market.

## 1.2 Taiwan's Trade Adjustment

Taiwan experienced substantial trade imbalances and unexpected exchange rate volatility in the 1980s. For evaluating the relationship between exchange rates and the trade balances, three problems of trade adjustment need to be empirically analyzed. They are: (1) Do exchange rates significantly influence trade flows? (2) How fast is the speed of the trade adjustment process? (3) What pattern does the short-run dynamic process of trade adjustment display?

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<sup>1</sup> Ueda (1983) first considered the importance of imported inputs in Japan's trade balance adjustment process.

Before developing a model to answer the above three questions, it is necessary to review and analyze the historical record of Taiwan's economic and trade developments to provide a basic background for understanding the trade adjustment problem.

### 1.2.1 Exchange rate and trade developments in Taiwan: 1949–1990s

In the 1950s, the economic development strategy of Taiwan was strongly affected by political considerations and concerns over national security. After a Nationalist-Communist civil war, the Communists controlled mainland China and the Nationalists retreated to Taiwan in 1949. In that year, the New Taiwan dollar was issued and the monetary relationship between Taiwan and mainland China was severed (Yu, 1975). At that time, the New Taiwan dollar was pegged to the U.S. dollar at the rate of five New Taiwan dollars (NT\$) to one U.S. dollar (US\$).

In the decade that followed, massive increases in Taiwan's population contributed to huge trade deficits.<sup>2</sup> During the period of 1950–1959, for example, the average trade deficit of Taiwan was US\$82 million per year (Yu, 1975, p. 53). During this period, Taiwan repeatedly devalued the New Taiwan dollar to improve its trade balance, and by 1961, the New Taiwan dollar–U.S. dollar exchange rate was forty to one. These sequential devaluation actions allowed Taiwan to gain a competitive advantage and helped to encourage exports but discourage imports.

In addition to this devaluation policy, Taiwan also undertook land reform policy in 1949–1953 which improved income distribution and contributed to more stable social conditions for the country's upcoming export growth in the early 1960s (Kuo, Ranis, and Fei, 1981, p. 48).

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<sup>2</sup> Two million immigrants from mainland China and a high birth rate of 3.5 percent per year caused Taiwan's population to increase from 6 million in 1948 to 9 million in 1955 (Taiwan statistical data book).

In the 1960s, Taiwan's slogan, "Everything for Export", reflected the country's export-oriented strategy for economic development. Two factors induced the adoption of this export-oriented strategy (Joint Economic Committee, 1987, p. 3). First, because Taiwan's domestic market was relatively small and its per capita income low, growth based on the domestic market was limiting; thus, Taiwan preferred an export-oriented rather than import-substitution strategy.<sup>3</sup> Second, Taiwan realized that continuation of a strong external relationship with other countries in the world (most notably its largest trading partners) was important for its self-defense and security. The export-oriented strategy allowed Taiwan to develop more intimate relationships with these major world powers.

The export-oriented strategy proved to be successful for Taiwan's economic development. From 1960 to 1980, Taiwan's real GNP increased 24-fold from US\$1.7 billion to US\$41.3 billion. The growth rate of real GNP averaged 8.2 percent per year in the 1950s, but increased to an average 9.1 percent per year in the 1960s, and 9.9 percent per year in the 1970s.<sup>4</sup>

The composition of Taiwan's exports also changed over this period, again reflecting the export-oriented policy. In 1952, only 8.1 percent of Taiwan's exports were industrial products, while 91.9 percent were agricultural raw materials and processed products. However, by 1970 industrial products accounted for 78.6 percent of Taiwan's exports, and the share of agricultural products had declined to 21.4 percent.<sup>5</sup>

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<sup>3</sup> Taiwan's population was 11 million and its per capita income was US\$143 in 1960 (Taiwan statistical data book).

<sup>4</sup> In the 1970s, the average annual economic growth rate of the world's major countries were: U.S., 2.8 percent; Japan, 4.3 percent; Germany, 2.6 percent; France, 3.2 percent; U.K., 2.0 percent; Italy, 3.8 percent; Korea, 9.6 percent; Singapore, 8.3 percent; and Hong Kong, 9.2 percent (Taiwan statistical data book).

<sup>5</sup> In 1994, 95.9 percent of Taiwan's exports were industrial products, but only 4.1 percent were agricultural products (Taiwan statistical data book).

In contrast, the composition of Taiwan's imports changed only moderately, reflecting the economy's limited supply of natural resources and dependence on imports of raw materials, energy, and other intermediate inputs for production. In 1952, 14.2 percent of Taiwan's imports were capital goods, 65.9 percent were agricultural and industrial raw materials, and 19.9 percent were consumer goods. In 1970, 32.3 percent of Taiwan's imports were capital goods, 62.8 percent were agricultural and industrial raw materials, and 4.9 percent were consumer goods.<sup>6</sup>

Taiwan's trade imbalance problem emerged in the 1970s as the country's trade surplus with the United States increased from US\$83 million in 1965 to US\$3.2 billion in 1980. At the same time, the trade deficit of Taiwan with Japan increased from US\$39 million in 1968 to US\$2.1 billion in 1980.

The 1973–1974 and 1979–1980 oil crises also exposed the vulnerability of the Taiwanese economy and trade performance to increases in energy costs. As shown in Figure 2, Taiwan's trade balance and total exports relative to GNP drastically decreased in these two periods. The first oil crisis caused Taiwan's real GNP growth rate to plummet from 12.8 percent in 1973 to 1.2 percent in 1974. The second oil crisis resulted in a steady drop in Taiwan's real GNP from 14.0 percent in 1978 to 8.5 percent in 1979, 7.1 percent in 1980, 5.8 percent in 1981, and 4.1 percent in 1982.

Taiwan's trade surplus problem became widened significantly in the 1980s. As Figure 3 shows, Taiwan has enjoyed huge and persistent trade surpluses since 1981. During the 1981–1993 period, the average value of Taiwan's trade surplus was US\$10 billion per year, or about 10 percent of GNP. In 1986, Taiwan's trade balance surplus peaked at US\$15 billion. The ratio of this trade surplus relative to GNP, which was equal

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<sup>6</sup> In 1994, 15.9 percent of Taiwan's imports were capital goods, 70.7 percent were agricultural and industrial raw materials, and 13.4 percent were consumer goods (Taiwan statistical data book).

to 20 percent, was the highest ever recorded for a major non-oil exporting country, and was more than four times that of Japan, Germany, and Korea, which were the other “large” trade-surplus countries in that year (Balassa and Williamson, 1987). As shown in Figure 4, the percentages of Taiwan’s trade balance relative to its GNP has been much higher than that of Japan since 1976.

Although Taiwan was proud of its excellent multilateral trade performances when its large trade surpluses emerged, bilateral trade with its major trade partners was extremely unbalanced; this led to trade frictions between Taiwan and its major trade partners. As mentioned earlier, Taiwan’s two key bilateral trading partners are the United States and Japan. In 1985, Taiwan’s trade with the U.S. was US\$19.5 billion, or 38.4 percent of Taiwan’s total trade of US\$50.8 billion. The United States is also Taiwan’s largest export market, accounting for 48.1 percent of Taiwan’s total exports in 1985. Moreover, the United States is Taiwan’s second-largest import market, accounting for 23.6 percent of Taiwan’s total imports in 1985. Given these numbers, it is apparent that the United States is the largest source of Taiwan’s trade surplus since the 1970s. In fact, as Figure 5 shows, during the period 1983–1987, the value of the trade surplus of Taiwan with the United States was higher than the value of Taiwan’s imports from the United States each year.

Although the United States severed formal diplomatic relations with Taiwan in 1979, Taiwan continues to maintain friendly relations with the United States in both political and economic matters. Recently, Taiwan applied for membership in the World Trade Organization (WTO) and is depending on U.S. support.

As Figure 5 shows, Taiwan first had a trade surplus of US\$39 million with the United States in 1968; this rapidly increased to US\$1.67 billion in 1977 and reached its highest point at US\$16.0 billion in 1987. In that year, Taiwan exported US\$23.6 billion worth of commodities to the United States but only imported US\$7.6 billion worth of goods; that is, Taiwan sold three times as much to the United States as did the United

States to Taiwan. However, Taiwan's trade surplus with the United States fell dramatically by 40 percent to US\$10.5 billion in 1988, but increased again by 15 percent to US\$12.0 billion in 1989. In 1990, the bilateral trade surplus declined again by 25 percent to US\$9.1 billion and continually decreased in subsequent years to US\$6.3 billion in 1994.

In startling contrast to its trade with the United States, Taiwan has continuously suffered from tremendous trade deficits with Japan since the 1960s when the bilateral trade deficit was US\$43 million. By 1981, Taiwan's trade deficit with Japan had blossomed to US\$3.5 billion; it then doubled to US\$7.0 billion in 1989 and doubled again to US\$14.2 billion in 1993 (Figure 6). In 1994, the trade deficit of Taiwan with Japan was US\$14.6 billion. As one example, in 1987, the trade deficit of Taiwan with Japan was US\$4.9 billion, with exports being approximately 60 percent of imports. Because of this, the growth rate of exports has to be 60 percent higher than that of imports just to keep the trade deficit from widening.

A number of reasons may explain the rapid expansion of Taiwan's trade surplus with the United States. One reason is that, as mentioned earlier in this section, Taiwan's currency was devalued 700 percent from NT\$5/US\$1 in 1949 to NT\$40/US\$1 in 1961. By undervaluing its currency against the U.S. dollar, Taiwan was able to gain a competitive edge in world markets and increase its trade surplus.

Another reason is that there has been an unambiguous transformation in the composition of Taiwan-U.S. trade over the 1960-1970 period. Of Taiwan's total exports to the United States, the share of agricultural raw materials and processed products decreased from 78.1 percent in 1955 to 26.1 percent in 1967 and 3.5 percent in 1980; the share of machinery and electrical equipment increased from 23.7 percent in 1968 to 29.2 percent in 1984, and the share of textile products decreased from 35.9 percent in 1970 to 22.2 percent in 1980. By 1980, industrial products accounted for approximately 95 percent of Taiwan's exports to the United States. At the same time that Taiwan was

improving the quality of its goods and increasing exports of these products, it was also decreasing its reliance on high-priced imports from the United States (Joint Economic Committee, 1987). One example is machinery and electrical equipment which decreased its share from 35.7 percent of Taiwan's imports from the United States in 1970 to 29.1 percent in 1980. Still another example is the manufacture of transportation equipment; the share of transportation equipment imports from the United States steadily decreased from 10.7 percent in 1970 to 6.3 percent in 1980 and 5.0 percent in 1982. The above statistics indicate that the trade composition of Taiwan-U.S. trade did, in fact, change during the 1960s to 1970s. By the 1980s, almost all of Taiwan's exports to the United States were manufactures, while Taiwan's imports from the United States were mostly nonmanufactured goods. This transformation in the composition of Taiwan's trade has contributed to an upward trend in Taiwan's trade surplus with the United States.

Still another reason for Taiwan's growing surplus with the United States is that U.S. imports are more sensitive to changes in income than are U.S. exports. Houthakker and Magee (1969) found the U.S. income elasticity of exports to be much higher than that of imports. Their estimates demonstrated that a one percent increase in U.S. income resulted in a 1.68 percent increase in U.S. imports, but a one percent increase in foreign income only evoked a 0.99 percent increase in U.S. exports. Thus, these unequal income elasticities of U.S. imports and exports partly explain the trade surplus of Taiwan with the United States.

A fourth reason for the trade surplus is that Taiwan imposed high tariffs on imported goods to discourage imports and protect its domestic industries. Whereas the average effective protection rate of U.S. consumer goods was only 25.9 percent in 1962, the average effective protection rate for Taiwan's consumer goods was 125.7 percent in 1966 (Yu, 1975, p. 164). To encourage exports, Taiwan also offered low interest rate loans to exporters and refunds on tariffs of imported inputs to exporters. A fifth and final

reason for the increasing trade surplus of Taiwan with the United States is that many U.S. multinational companies sold their Taiwan-made products in the United States (Joint Economic Committee, 1987).<sup>7</sup>

Several factors may explain Taiwan's huge trade deficit with Japan. One factor is that Taiwanese consumers have historically had a strong preference for Japanese-made products. A second factor is that Taiwan relies on Japanese-made semi-manufactures to produce its final manufactured goods. A study by the Joint Economic Committee of the U.S. Congress (1987) also indicated that Japan has some advantages over its competitors in marketing goods in Taiwan. Because Japan controlled Taiwan for 50 years (1896–1945), many elderly Taiwanese speak Japanese making it convenient for Japan's exporters to communicate with Taiwan buyers. In addition, Japanese firms have employed aggressive marketing techniques and typically offer better after-sale service than do firms from other countries.

From the above it is easy to see why bilateral trade between Taiwan and its major trade partners have been asymmetric, and particularly in the past decade, this trade disequilibrium problem has caused some friction in the international trade relationships between Taiwan and these countries. In the 1980s, for example, the United States repeatedly accused Taiwan of manipulating the value of its currency to gain trade surpluses and urged an appreciation of the New Taiwan dollar relative to the U.S. dollar. Responding to U.S. pressure, the New Taiwan dollar significantly appreciated against the U.S. dollar in the late 1980s (see Figure 7, for example, which shows the exchange rate of

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<sup>7</sup> The effect of changes in globalization of production on a Multinational Enterprise host-country's trade balance depends primarily on the changes in global pattern of trade. If the increase in final good exports of host-country to source-country exceeds the increase in intermediate good imports of host-country from source-country, then the host-country's trade balance improves. In addition, the increase in intermediate goods trade between host and source countries may influence the responsiveness of trade flows to changes in exchange rate over time. Hooper and Marquez (1993) assert that the intermediate goods trade tends to reduce the sensitivity of trade flows to exchange rate changes.

the NT\$ against the US\$ during the first quarter of 1974 to the fourth quarter of 1994). Although the Taiwan Central Bank announced that it had adopted a floating exchange rate regime in 1979 (see shadowed area (1) in Figure 7), pressure from the United States continued with the U.S. arguing that Taiwan had artificially undervalued its currency in order to facilitate its “export-oriented” economic development strategy (Lenz, 1991; Howell and Glenn, 1992). Answering to this U.S. pressure, the Taiwan authorities moved exchange rate determination toward a more market-oriented direction and the New Taiwan dollar appreciated from NT\$40.40/US\$1 in the third quarter of 1985 to NT\$28.55/US\$1 in the fourth quarter of 1987 (see shadowed area (2) in Figure 7).

Despite these significant appreciations, the United States still was not satisfied with this result and protested that the Taiwan Central Bank was “leaning against the wind” to slow the rate of appreciation of the New Taiwan dollar by intervening in the foreign exchange market. Although the New Taiwan dollar had appreciated by 28 percent between the third quarter of 1985 and the third quarter of 1988, the rate of appreciation was, in fact, much lower than that of the Japanese yen (46 percent) and the German mark (40 percent) over the same period. In October 1988, the U.S. Treasury lodged a formal complaint against Taiwan for allegedly manipulating the exchange rate to maintain the competitiveness of its goods in international markets (Howell and Glenn, 1992). From NT\$28.93/US\$1 in the third quarter of 1988, the New Taiwan dollar appreciated further to NT\$25.60/US\$1 in the third quarter of 1989 (see shadowed area (3) in Figure 7). Still the United States remained unsatisfied and in May 1992, the U.S. Treasury cited as evidence the fact that Taiwan's international reserves had increased far quicker than its accumulated trade balance (Baum, 1992). This report brought about expectations of further appreciation of the New Taiwan dollar, and the New Taiwan dollar indeed appreciated to NT\$24.65/US\$1 in the second quarter of 1992 from NT\$25.51/US\$1 in the first quarter of 1992 (see shadowed area (4) in Figure 7). Although the U.S. Treasury again accused Taiwan of manipulating

its currency to gain trade surpluses in December 1992 (*Washington Post*, 1992), this time the Taiwan currency did not appreciate, but instead slightly depreciated from NT\$25.40/US\$1 in the fourth quarter of 1992 to NT\$26.11/US\$1 in the first quarter of 1993 (see shadowed area (5) in Figure 7). Thus the high-speed appreciation period of the New Taiwan dollar had ended, and the value of Taiwan's currency had stabilized.

As mentioned earlier, one noteworthy fact is during 1985–1987 and 1990–1991, Taiwan's international reserves were augmented at a much faster rate than its accumulated trade balances (Figure 8). This suggests that the Taiwan Central Bank intervened in the foreign exchange market during these two periods to reduce the speed of appreciation of the New Taiwan dollar by purchasing U.S. dollars. The ratios of Taiwan's international reserves to GNP and to annual imports are huge, and Taiwan has the largest amount of international reserves of any major country.<sup>8</sup> The accumulation of this huge amount of international reserves largely arose out of political concerns and security defense requirements.<sup>9</sup> However, the rapid increase in international reserves in the late 1980s also led to an expansion in money supply and a higher inflation rate. From 0.5 percent in 1987, Taiwan's inflation rate rose to 1.3 percent in 1988, 4.4 percent in 1989, and 4.1 percent in 1990, leading to some concerns by Taiwan officials. As noted by one Taiwan legislator: "The foreign exchange reserve has become a burden, not an asset" (*Business Week*, 1987).

Another noteworthy fact is that although the exchange rate of the New Taiwan dollar against the U.S. dollar started to appreciate in 1985, Taiwan's trade surplus with the United States continued to increase for two more years (Figure 9). Taiwan's exports to the United States, which is the most important export market for Taiwan's goods, are

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<sup>8</sup> The ratio of Taiwan's international reserves to GNP was 77.6 percent in 1987 as compared to 3.3 percent for Japan in the same year.

<sup>9</sup> Taiwan's international reserves accounted for 230 percent of annual imports in 1987, while in that year, the ratio of Japan's international reserves to annual imports was only 30 percent.

composed of a few major items, namely, machinery and electrical equipment (44 percent), textile products (12 percent), and basic metals and articles (10 percent; see Table 1). A reduction in Taiwan's trade surplus with the United States means that these key export items may undergo limited growth and a painful adjustment processes. Exports dominate Taiwan's economic growth and development. As such, the effects of a decrease in Taiwan's trade surplus will inevitably influence Taiwan's export sector and the country's overall economic development.

### 1.2.2 The problems of trade adjustment in Taiwan

So far this study has focused on the analysis of Taiwan's experience of trade imbalance over the past two decades, documenting the emergence of Taiwan's trade imbalance as a "problem." However, the advantage and disadvantage of trade imbalances are long standing issues of debate among international economists. Before I analyze the role of exchange rate adjustment in eliminating trade imbalances, it may be useful to examine the perspectives of economists and policymakers on the issue.<sup>10</sup> The important question to be answered then is why do we care about the trade balance? That is, what makes the trade balance account a problem?

To discuss these questions, it is instructive to first review the definitions of the current account and trade account balances. The current account balance shows the balance of trade in goods and services plus net investment income and unilateral transfers; that is, the current account measures the net debt of a country (Pilbeam, 1992). It measures a country's broadest trade pattern with the rest of the world (Hakkio, 1995, p. 12). However, the most publicized component in the current account and even in the balance of payments is the merchandise balance of trade (Rivera-Batiz and Rivera-Batiz, 1985). The

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<sup>10</sup> Recent discussions about these issues include Chrystal and Wood (1988), Levi (1990), Krugman (1991), and Hakkio (1995).

merchandise trade balance measures the difference between merchandise exports and imports, it provides a summary of a country's trade patterns in goods (Rivera-Batiz and Rivera-Batiz, 1985). This study focuses on an analysis of the merchandise trade balance. One reason for doing this is that politicians are concerned about this account. A second reason is that merchandise exports and imports are the most important transactions of the current account (Hakkio, 1995, p. 12).

There are various reasons why people are concerned about the trade balances. In the United States, popular concern over the trade deficit reflects the general notion that the deficit is an indication of a decline in the competitiveness of U.S. goods in the world market (Bryant et al., 1988). If the United States continues to run a trade deficit, then the United States cannot compete with other countries, and indicates that something is fundamentally wrong in the U.S. economy. The United States is also concerned about the "unfair" trade practices when other countries do not allow U.S. goods to freely enter their domestic markets (Cline, 1994).

Economists sometimes worry about trade deficits as well. For example, if a country has persistent trade deficits, then its foreign exchange reserves may run out, reducing the country's ability to maintain the domestic exchange rate by intervening in the foreign exchange market (Ethier, 1988). If a country runs out of foreign exchange reserves, then this country cannot use the exchange rate as a policy tool to maintain its policy targets whether it be full employment or controlling inflation.<sup>11</sup> Persistent trade deficits implies that a country is dissaving internationally and requires the country to borrow from abroad. Although the residents of this country are currently living above their means, future interest payments on the debt may cause their descendants to live below their means and reduce this country's welfare in the future (Hakkio, 1995).

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<sup>11</sup> Although the exchange rate regime is currently a flexible system, in actuality many of the major countries still intervene in foreign exchange markets (Chrystal and Wood, 1988).

However, some economists are not concerned about trade deficits particularly in cases where short-term trade deficits are followed by short-term trade surpluses and there is balanced trade over the long term. A trade deficit associated with new capital formation may permit high investment, and thus an increase in the growth rate of output; that is, a trade deficit may be healthy for a country (Chrystal and Wood, 1988). It is, therefore, more important to consider the composition of the trade deficit rather than the size of the trade deficit.

Although economists commonly claim that a trade deficit due to importing capital goods may be helpful in promoting future production and exports, these economic benefits are often difficult to see. Therefore, politicians typically prefer trade surpluses to trade deficits reflecting the mercantilist notion that trade surpluses are an effective policy means of accumulating foreign assets (Levi, 1990, pp. 95–96). One example of this was mentioned earlier in section 1.2.1; Taiwan has had persistent multilateral merchandise trade surpluses since the 1980s, implying that Taiwan earned foreign assets while its welfare was below its long-run average. Still another reason for the preference for trade surpluses is that the modern mercantilism focuses on the relationship between the trade balance and job opportunities. A country with a trade deficit may cause its residents to lose job opportunities while a country with a trade surplus may have its residents gaining job opportunities (Cline, 1994). This is so because everything else equal, a trade deficit means lower demand for domestic goods and domestic country job losses. The opposite is true for a trade surplus country. However, the job losses that concern modern mercantilists do not imply that the national welfare definitely falls. The changes in national welfare depend on whether the job loss results from a loss of this industry's competitiveness. If one industry has lost its competitiveness, then the job loss of this industry may accompany with employment gains in other sectors. In this situation, the national welfare may become better rather than worse.

Even if there are good economic reasons to be concerned about overall trade or current account balances, it is not clear that bilateral imbalances represent a problem. Economists sometimes assert that there is no reason to expect a country's bilateral trade to balance. For example, Taiwan, Japan, and the United States constitute a "triangular trade" relationship with Taiwan depending on Japanese-made intermediate inputs for its production but relying on the U.S. market to sell its final goods. "Taiwan's trade deficit with Japan is closely linked to its surplus with the United States. A substantial proportion of the Japan deficit and the U.S. surplus consists of intermediate goods imported to Taiwan from Japan and assembled for export to the United States" (Howell and Glenn, 1992, p. 314). Thus, Taiwan's trade surplus with the United States and its trade deficit with Japan may naturally coexist.

However, from a political view point, politicians in Taiwan and the United States have become seriously concerned about the huge and persistent trade deficit of Taiwan with Japan and the trade surplus of Taiwan with the United States in the past decade. As Figure 10 shows, while the trade surplus of Taiwan with the United States decreased from US\$16.0 billion in 1987 to US\$6.8 billion in 1993, the trade deficit of Taiwan with Japan increased from US\$4.9 billion to US\$14.2 billion in the same period. Therefore, trade deficit countries often perceive the trade imbalance as the outcome of "unfair" trade practices with the trade surplus countries employing the beggar-thy-neighbor policies to gain job opportunities, and thereby worsening job opportunities in the trade deficit countries. Thus, protectionist actions have been adopted to attain the balanced trade goal. These political arguments have resulted in the trade conflicts and motivated the trade balance adjustment between Taiwan and its major trade partners.

As presented in previous sections, Taiwan has remarkable trade imbalances in both its multilateral and bilateral trade. The sources of multilateral trade imbalance mainly come from Taiwan's bilateral trade surpluses with the United States and bilateral trade deficits

with Japan. Taiwan's multilateral trade balance is strongly influenced by Taiwan-U.S. and Taiwan-Japan bilateral trade balances. The analysis of Taiwan-U.S. and Taiwan-Japan bilateral trade imbalances has implications for understanding Taiwan's multilateral trade imbalances. Therefore, this dissertation focuses on the analysis of Taiwan-U.S. and Taiwan-Japan bilateral trade without considering other Taiwan's bilateral trade flows. This study also proceeds on the assumption that balanced trade is an important objective of politicians, reflecting political reality. Movement toward overall trade balance may also be a desirable economic goal, although the welfare implications of such policies problem are not directly addressed.

### 1.2.3 Other elements of Taiwan's economic adjustment program

Although this study focuses on an analysis of the role of exchange rates on Taiwan's trade balance adjustment, other micro and macroeconomic adjustment programs that have been undertaken by Taiwan are worth mentioning. This section reviews the main programs that have been implemented.

Realizing that its huge trade surplus with the United States was the cause of the trade conflict with the United States and the increased protectionist pressures, Taiwan adopted a number of measures to reduce its huge bilateral trade surplus. One measure adopted is the legislation of an intellectual property protection law. The United States has repeatedly accused Taiwan of imitating American commodities ("Taiwan's trade surplus", 1990). As noted by Ethier (1988), "Taiwan is probably the largest single source" of counterfeit goods. According to U.S. government sources, 60 percent of all counterfeit products made in the world come from Taiwan (Grossman and Shapiro, 1988), and these counterfeit goods result in America losing US\$750 million in sales per year (Moore, 1989). An article in *Life* magazine reports that counterfeit products from Taiwan result in a loss of 200,000 jobs and about US\$7 billion in sales in the United States every year (Whipple,

1984). In 1984, the U.S. Congress enacted the "Trademark Counterfeiting Act" to investigate Taiwan's counterfeit behavior (Grossman and Shapiro, 1988). To respond to these accusations, Taiwan has legislated an intellectual property protection law to eliminate domestic counterfeit activities.

A second measure that has been adopted to reduce trade tensions is the opening of the domestic market. In the 1980s, Taiwan moved its economic development strategy toward "internationalizing, liberalizing, and systematizing" (Lindenberg and Ramirez, 1989). "Internationalization" refers to the opening of Taiwan's domestic market to the United States and other countries. The most important U.S. goods to Taiwan are computers, communication, environmental protection, and high-tech equipment. "Liberalization" refers to providing U.S. and other countries' commodities with an equal chance of competing with Taiwan-made products in Taiwan. In the past, the Taiwan government provided exporters with subsidies and low-interest loans reflecting the adoption of an export-oriented trade policy. To avoid U.S. trade retaliation, the government has since canceled most of these export subsidies and loans. "Systematization" refers to the elimination of all trade barriers; that is, decreasing tariff rates and abolishing trade-restricting rules. Although Taiwan's total average tariff rate decreased from 27.2 percent in 1985 to 11.6 percent in 1988 (Huang, 1990), they are still higher than the overall average U.S. tariff rate which was 5 percent in 1984 (Ethier, 1988). Nevertheless, the adoption of an open domestic market policy has gradually changed the composition of Taiwan's imports. In particular, the share of consumer goods of Taiwan's total imports increased from 5.8 percent in 1980 to 13.4 percent in 1994.

A third measure that has been followed is expansionary fiscal policy which involves a series of sizable economic plans for improving Taiwan's standard of living. According to the Six-Year Plan, a total US\$300 billion, or 150 percent of Taiwan's GNP, is to be spent on infrastructure and more construction is planned. This spending has stimulated Taiwan's

imports from the United States and other countries and is likely to continue to reduce Taiwan's trade surplus. The growth rate of Taiwan's annual government capital expenditures increased from 2.5 percent in 1985 to 9.7 percent in 1986, 10.2 percent in 1987, 21.5 percent in 1988, and a startling 148.7 percent in 1989. Over the same period, Taiwan's government budget deficit increased from NT\$3.1 billion in 1984 to NT\$318.0 billion in 1989.

A fourth measure is the liberalization of financial markets. Because of a long period of foreign exchange control, Taiwan's enterprises and private industries lack access to well-developed foreign investment channels. This is also the main reason why money gambling games have been popular in Taiwan in recent years. Taiwan's stock index often fluctuated dramatically, and the total turnover of the Taiwan stock market is now the third largest in the world ("Taiwan's trade surplus", 1990), standing behind only the New York Stock Exchange and the Tokyo Stock Exchange. Because Taiwan experienced huge trade surpluses in the last decade, it accumulated US\$83 billion in foreign exchange reserves, the highest in the world in 1992. However, too much foreign exchange reserves would cause the money supply to increase and could even result in inflation (Ethier, 1988). Therefore, the central bank of Taiwan reduced its intervention in the foreign exchange market, allowed the exchange rate to be determined by market forces, and has permitted more foreign banks to establish branches in Taiwan.

Still another measure to reduce Taiwan's trade surplus with the United States is the diversification of Taiwan's export markets. Instead of concentrating on the U.S. market, Taiwan has diversified its export markets to other countries. The percentage of Taiwan's exports to the United States has decreased from 48.1 percent in 1985 to 36.2 percent in 1989, and 26.2 percent in 1994. In the same years, the share of Hong Kong in Taiwan's exports has increased from 8.3 percent in 1985 to 12.7 percent in 1990, and 22.9 percent in 1994. Since 1990, Hong Kong has replaced Japan as Taiwan's second-largest export

market. However, most of this expansion in Taiwan–Hong Kong bilateral trade is due to indirect trade between Taiwan and China.

In addition to the above-mentioned measures, exchange rate policy may also be an effective method to balance Taiwan's trade account. This study presents an empirical analysis of the importance of the exchange rate on Taiwan's trade adjustment. Before beginning with a formal empirical analysis, it is useful to analyze several important variables of trade development to explore the relationship that may exist between exchange rates and trade balances. This is the focus of the next section.

### 1.3 Preliminary Examination of Taiwan's Exchange Rate–Trade Balance Relationship

Before developing an empirical model to study Taiwan's trade adjustment process, simple correlations of the nominal and real exchange rates and trade balances are undertaken in this section. Using this simple technique, insights into how the model is to be structured can be gained.

Table 2 presents the correlation between the nominal and real exchange rates.<sup>12</sup> For both the level and rate of change, the correlations are all positive, but the correlations between the nominal and real exchange rates for Taiwan–U.S. are smaller than that for Taiwan–Japan. These results indicate that nominal and real exchange rates tend to move in the same direction. As Figures 11 and 12 show, the exchange rates of the New Taiwan dollar relative to the Japanese yen in nominal and real terms are roughly similar in magnitude. However, as Figures 13 and 14 show, the nominal and real exchange rate of

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<sup>12</sup> The real exchange rate is defined as the nominal exchange rate multiplied by the ratio of the foreign price level to the domestic price level. The real exchange rate is often used as a measure of the competitiveness of domestic goods relative to foreign goods (Edwards, 1989, p. 5). Although Taiwan adopted a fixed exchange rate regime before 1979, the real exchange rate is not fixed because inflation rates in domestic and foreign countries differ. Therefore, even in this earlier period, changes in the real exchange rate may have played a role in the trade balance adjustment.

the New Taiwan dollar relative to the U.S. dollar differ dramatically in certain years; the same is true for the rate of change in the exchange rate. The reason for the difference of correlations between exchange rates for Taiwan–U.S. and exchange rates for Taiwan–Japan is that the real exchange rate is the nominal exchange rate adjusted for inflation. As shown in Figure 15, the differences between the inflation rates of Taiwan and Japan are relatively smaller than those of Taiwan and the United States.

As shown in Figure 13, real exchange rates were sustained at a stable level during the 1965–1973 period. However, in the 1974 oil crisis, an extremely high inflation rate in Taiwan brought about a sudden appreciation of the real exchange rate. Subsequently, over the 1975–1985 period, the real exchange rate tended to depreciate; over the same period, the domestic inflation rate remained relatively low.<sup>13</sup> During the 1986–1987 period, real exchange rates experienced a drastic appreciation as the nominal exchange rate of the New Taiwan dollar escalated from NT\$39.85/US\$1 in 1985 to NT\$28.55/US\$1 in 1987. After 1987, real exchange rates were restored to relatively stable levels again since nominal exchange rates were generally constant.

In summary, during the 1965–1985 period, real exchange rates were mainly influenced by changes in inflation rates; after that period, real exchange rates were predominantly influenced by changes in nominal exchange rates.

The real trade balance is a price-adjusted nominal trade balance and, thus, may be a more appropriate measurement to represent the summary of a country's trade pattern.

Table 3 presents the correlation between the nominal and real trade balances. In terms of both level and rate of change, the correlations between the nominal and real trade balances

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<sup>13</sup> In 1974, Taiwan's wholesale prices increased by 40.6 percent and consumer prices increased by 47.5 percent. During the 1975–1978 period, wholesale price index rose by an average of 1.0 percent per year and the consumer price index increased by an average 5.1 percent per year. However, in the 1979–1980 second oil crisis period, wholesale prices increased by 18.0 percent per year, while consumer prices jumped by 17.7 percent per year (Taiwan statistical data book).

of Taiwan–U.S. trade are much higher than that of Taiwan-Japan trade. The nominal and real trade balances of Taiwan with the United States generally move in the same direction (Figure 16), and the rate of change in the nominal and real trade balances of Taiwan with the United States roughly move together (Figures 17). However, as Figures 18 and 19 show, the real trade balance of Taiwan with Japan is sometimes very different from the nominal trade balance both in terms of levels and rates of change.

Figure 20 demonstrates that Taiwan's real exchange rates and real trade balances with the United States follow a close relationship, but with a time lag. This suggests that the real exchange rate influences the real trade balance but with a J-curve pattern adjustment; that is, real trade balances do not respond until one to two years after the real exchange rate has changed. However, as Figure 21 shows, Taiwan's real exchange rate and real trade balance with Japan roughly followed an upward trend, but the two did not move together closely.

#### 1.4 Organization of the Dissertation and Major Conclusions

The thesis is organized as follows. In this chapter, the objectives of this dissertation were introduced and the problems of trade adjustment in Taiwan were highlighted. Chapter 2 reviews the basic theoretical and empirical framework of the trade adjustment literature including discussions of basic models and critical elasticity conditions, price and income elasticities estimation, and the J-curve effect. In Chapter 3, a partial equilibrium empirical model of Taiwan's trade balance adjustment is presented and the specification and econometric methodology are discussed. Chapter 4 considers some well-known econometric issues surrounding estimation of the trade equations, specifies and estimates the trade flow functions using a modern time-series method, and evaluates the effects of changes in the exchange rate on trade flows between Taiwan and its largest two trade partners, the United States and Japan. In Chapter 5, the conclusions of the analysis

are presented, the limitations of the study are discussed, and areas in which further research can be done are suggested.

The major conclusions of this dissertation are as follows:

1. In the long run, the exchange rate tends to be an effective tool in reducing Taiwan's trade imbalance since Taiwan's exports and imports are found to be sensitive to changes in exchange rates. In addition, it is determined that Taiwan's currency depreciation has had a significant and positive effect on the country's trade balance. These findings generally support the traditional findings of international trade economists that have been challenged by recent studies (see, for example, Rose and Yellen, 1989; Rose, 1990 and 1991; and Hsing, 1993).

2. However, in the short run, Taiwan's exports and imports tend to be insensitive to changes in exchange rates; that is, the J curve-effect may exist and Taiwan's trade flows may exhibit an initial perverse responses to exchange rate movements.

3. The trade flows between Taiwan and Japan tend to be less sensitive to exchange rate changes than the trade flows between Taiwan and the United States. One potential explanation for this is that the composition of trade between Taiwan and the United States and Taiwan and Japan differ.

4. The supply effect of import prices on Taiwan's exports does not dominate the effect of an exchange rate change on the trade balance in the long run, but appears to have some impact in the short run.

## CHAPTER 2

### A SURVEY OF THE EMPIRICAL TRADE ADJUSTMENT LITERATURE

Literature on the responsiveness of trade flows to changes in the exchange rate are abundant. Comprehensive survey articles have been written by Houthakker and Magee (1969), Leamer and Stern (1970), Magee (1975), Stern et al. (1976), Artus and Knight (1984), Goldstein and Khan (1985), and Hooper and Marquez (1993). In these articles, the export and import functions were typically presented as the basic model with different elasticities conditions for trade balance improvement being assumed. In this chapter, the export and import functions that have been employed in other studies are reviewed and the critical elasticities conditions are discussed.

#### 2.1 Basic Models and Critical Elasticity Conditions

The export and import functions used in the models of exchange rate and trade adjustment are derived from theories of consumption and production (Goldstein and Khan, 1985). According to consumer theory, both the demand functions for exports and imports depend negatively on relative prices and positively on income. On the basis of production theory, the supply functions of exports and imports are positively related with relative prices.

##### 2.1.1 The Bickerdike-Robinson-Metzler model

The Bickerdike-Robinson-Metzler model, developed by Charles Bickerdike (1920), Joan Robinson (1937), and Lloyd Metzler (1948), is a standard and popular model of the “elasticity approach” to an analysis of the behavior of export and import markets. The Bickerdike-Robinson-Metzler model includes an independent export market and import market. Because each market includes demand and supply functions, the Bickerdike-

Robinson-Metzler model can be used to explain the effects of exchange rate changes on segregated export and import markets.

Mathematically, the Bickerdike-Robinson-Metzler model is defined as follows (Dornbusch, 1988):

- (1) export supply function:  $x^s = x^s(P_x)$
- (2) export demand function:  $x^d = x^d\left(\frac{P_x}{e}\right)$
- (3)  $x^s = x^d = x$
- (4) import supply function:  $m^s = m^s(P_m)$
- (5) import demand function:  $m^d = m^d(e \cdot P_m)$
- (6)  $m^s = m^d = m$
- (7)  $B = P_x \cdot x - e \cdot P_m \cdot m$

where  $x$  = export quantity

$m$  = import quantity

$x^s$  = export supply

$x^d$  = export demand

$m^s$  = import supply

$m^d$  = import demand

$e$  = nominal exchange rate (i.e., units of domestic currency per unit of foreign currency)

$P_x$  = export price in terms of the domestic currency

$P_m$  = import price in terms of the foreign currency

$B$  = nominal trade balance in terms of the domestic currency.

On the export side, equation (1) is the export supply function which depends positively on export price; equation (2) is the export demand function which depends negatively on export price; and equation (3) is the equilibrium condition for the export

market. The import supply function, equation (4), depends positively on import price; equation (5) is the import demand function which depends negatively on the import price; and the equilibrium condition for the import market is represented by equation (6). Equation (7) shows that the nominal trade balance in terms of the domestic currency is the difference between exports and imports.

One significant drawback of the Bickerdike-Robinson-Metzler model is that it is only a partial equilibrium model of the elasticity approach. Two simplifying assumptions are made in order to focus on an analysis of exchange rate effects. One assumption is that domestic and foreign incomes are fixed under full employment; as a result, incomes play no role in this model. Another restricting assumption is that the prices of domestically competitive goods in the two countries are also fixed so that changes in nominal exchange rates are fully reflected in the relative prices of traded goods.

### 2.1.2 The Bickerdike-Robinson-Metzler condition and its special cases

If we assume a large country with finite price elasticities, then partially differentiate equations (1)–(7) above with respect to the exchange rate and make appropriate substitution, we can derive the well-known Bickerdike-Robinson-Metzler condition:

$$(8) \quad \left( \frac{P_x^0 \cdot x^0}{e^0 \cdot P_m^0 \cdot m^0} \right) \cdot \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} > 1$$

where  $x^0$  = initial export quantity

$m^0$  = initial import quantity

$e^0$  = initial nominal exchange rate (i.e., units of domestic currency per unit of foreign currency)

$P_x^0$  = initial export price in terms of the domestic currency

$P_m^0$  = initial import price in terms of the foreign currency

$d_x$  = price elasticity of export demand

$s_x$  = price elasticity of export supply

$d_m$  = price elasticity of import demand

$s_m$  = price elasticity of import supply.

Equation (8) is a critical elasticity condition for a positive effect of a devaluation on the trade balance. That is, when the domestic currency is devalued by one percent, then on the export side, the export price increases by  $\left(\frac{d_x}{s_x + d_x}\right)$  percent, export quantity increases by  $\left(\frac{s_x \cdot d_x}{s_x + d_x}\right)$  percent, and export revenue consequently increases by  $\left(\frac{d_x \cdot (1 + s_x)}{s_x + d_x}\right)$  percent. Similarly, on the import side, the import price increases by  $\left(\frac{s_m}{s_m + d_m}\right)$  percent, import quantity decreases by  $\left(\frac{s_m \cdot d_m}{s_m + d_m}\right)$  percent, and import expenditure thus increases by  $\left(\frac{s_m \cdot (1 - d_m)}{s_m + d_m}\right)$  percent. Subsequently, the trade balance will improve if the increment of export revenue exceeds the rise in import expenditure. When the initial export value is  $(P_x^0 \cdot x^0)$  and the initial import value is  $(e^0 \cdot P_m^0 \cdot m^0)$ , then the trade balance improvement condition is as follows:

$$(8)' \quad P_x^0 \cdot x^0 \cdot \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} > e^0 \cdot P_m^0 \cdot m^0 \cdot \frac{s_m(1 - d_m)}{(s_m + d_m)}$$

If both sides of equation (8)' are divided by  $(e^0 \cdot P_m^0 \cdot m^0)$ , equation (8)' can be written as equation (8).

The first term of equation (8) implies that the initial trade account may be unbalanced. When imports initially exceed exports, then a devaluation must increase exports to offset the increase in total import expenditure. That is, it may be difficult for equation (8) to be satisfied. On the other hand, if there is a large trade surplus in the initial period, then the Bickerdike-Robinson-Metzler condition is more easily satisfied.

To simplify the complicated Bickerdike-Robinson-Metzler condition, economists have typically assumed that there is excess production capacity and labor unemployment in both the domestic and foreign economies.<sup>14</sup> Thus, supply elasticities are assumed to be infinite and supply prices are fixed for both exports and imports. Under the assumption of initially balanced trade and infinite supply elasticities, the Bickerdike-Robinson-Metzler condition can be reduced to the famous Marshall-Lerner condition:

$$(9) \quad d_x + d_m > 1.$$

That is, with infinite supply elasticities, the necessary and sufficient condition for a positive effect of a devaluation on the trade balance is that the sum of the demand elasticities of exports and imports is greater than one in absolute value. When the domestic currency is devalued by one percent, then on the import side, import price increases by one percent and import quantity decreases by  $d_m$  percent. Therefore, the import expenditure increases by  $(1 - d_m)$  percent. On the export side, export price remains unchanged, but export quantity, and therefore export revenue, increases by  $d_x$  percent. Consequently, the trade balance will improve if the increment of export revenue exceeds the rise in import expenditure. That is, if the percentage change in exports exceeds that for imports, then a country can improve its trade balance by devaluing its currency.

However, in the case of a small country, it can be reasonably assumed that the price elasticities for both the export demand and import supply are infinite (Magee, 1975). The reason for assuming an infinite export demand elasticity is that a small country cannot affect the world market price and can sell all it wants at a fixed export price. An infinite import supply elasticity implies that a small country only imports a tiny part of the world's goods, and, thus, cannot influence the world import price.

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<sup>14</sup> These assumptions reflect the historical background of trade theory (for example, the 1930s during the Great Depression) and are consistent with the hypotheses of Keynes (Dernburg, 1989).

Using equation (8), the trade balance improvement condition of a small country case is that the sum of the export supply elasticity and the import demand elasticity must be greater than zero:

$$(10) \quad s_x + d_m > 0.$$

Equation (10) implies that a small country can always improve its trade balance by devaluing its currency since the devaluation raises export and import prices equally. Therefore, even without changes in quantity, the trade account remains balanced because the changes in the value of exports and imports are even; but because import quantity does decrease and export quantity does expand, as a result, the trade balance of the small country will unambiguously improve.

The above discussion of the condition for trade balance improvement for three cases (i.e., a large country, a small country, and infinite supply elasticities) of the Bickerdike-Robinson-Metzler model is summarized in Table 4.

### 2.1.3 Traditional partial equilibrium empirical models of determinants of trade flows

The verdict on the validity of the critical elasticity condition is an empirical question and hundreds of empirical studies have examined this question. In many of these studies, the price elasticities of export and import supplies are assumed to be infinite to avoid supply-side considerations (Leamer and Stern, 1970; Magee, 1975; Rose and Yellen, 1989; Rose, 1991). Therefore, the estimated functions are usually the export demand and import demand functions.

As mentioned earlier in section 2.1, one major omission from the Bickerdike-Robinson-Metzler model is the role of income effects; that is, the assumption is that domestic and foreign incomes are fixed. However, according to the theory of demand, income may be an important factor of demand determination for exports and imports; thus, income is generally included as an additional explanatory variable in the standard two-

country models of trade (Rose and Yellen, 1989). I similarly introduce income terms into the empirical analysis below.

If the import and export demand functions are assumed to be homogeneous of degree zero in terms of price and income (implying no money illusion), then the standard trade model (Leamer and Stern, 1970) can be expressed as:

$$(11) \quad \text{Export demand function: } x = x(y^*, \frac{P_x}{P^*})$$

$$(12) \quad \text{Import demand function: } m = m(y, \frac{P_m}{P})$$

where  $x$  = quantity of exports

$m$  = quantity of imports

$y$  = real domestic income

$y^*$  = real foreign income

$\frac{P_x}{P^*}$  = export price relative to the foreign price level

$\frac{P_m}{P}$  = import price relative to the domestic price level.

If, as is generally assumed, the domestic country is a price-maker in the export market and a price-taker in the import market, then we can simply suppose that the import price is equal to the foreign price times the nominal exchange rate and that the export price is equal to the domestic price divided by the nominal exchange rate. Consequently, the export and import demand functions can be rewritten as a function of the real exchange rate (Hooper and Marquez, 1993):

$$(13) \quad \text{Export demand function: } x = x(y^*, \frac{e \cdot P^*}{P})$$

$$(14) \quad \text{Import demand function: } m = m(y, \frac{e \cdot P^*}{P})$$

where  $e$  = nominal exchange rate (units of domestic currency per unit of foreign currency)

$P$  = domestic price level

$$P^* = \text{foreign price level}$$

$$\frac{e \cdot P^*}{P} = \text{real exchange rate}$$

and the other variables are defined as above.

The real exchange rate represents the actual competitiveness of domestic goods relative to foreign goods. When the real exchange rate depreciates, then domestic goods become more competitive than foreign goods and, consequently, domestic exports will expand and imports will fall.

Since the trade balance is the difference between a country's exports and imports, combining equations (13) and (14), the trade balance can be written in real terms as:

$$(15) \quad b = x\left(y^*, \frac{e \cdot P^*}{P}\right) - m\left(y, \frac{e \cdot P^*}{P}\right)$$

where  $b$  = real trade balance and the other variables are as defined earlier.

If the reduced form is considered, then the trade balance function becomes (Rose and Yellen, 1989):

$$(16) \quad b = b\left(y, y^*, \frac{e \cdot P^*}{P}\right).^{15}$$

## 2.2 Estimation of Price and Income Elasticities

Since the 1940s and early 1950s, it has been common for researchers to estimate export and import demand functions and measure price and income elasticities. After the 1950s, however, research in this field expanded with the development of many multivariate and simultaneous econometric trade models that were estimated for the same purposes but

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<sup>15</sup> The advantage of this reduced form is that even if the structural form is not known, the results can still be directly estimated with the reduced-form equation and the structural parameters need not be specified (Rose and Yellen, 1989). However, the disadvantage of the reduced form is that it is not always possible to derive the structural parameters from the estimates of the reduced-form equations because of an identification problem. A more detailed discussion of the identification problem is given in Chapter 4.

aided by computer technology (Leamer and Stern, 1970). Since then, the number of studies that estimate price and income elasticities has grown at a phenomenal rate.

The range for the estimated export and import price elasticities is wide (Hooper and Marquez, 1993). For example, Hooper and Marquez (1993) summarized the results of numerous empirical trade studies in a chronological table which shows that the price elasticities of U.S. exports vary from -0.20 to -3.75. The price elasticities of Japanese exports cover an even wider range from a positive number, 2.47, to a huge negative number, -11.70. The price elasticities of German exports also range widely from 1.70 to -5.00. For imports, the ranges of price elasticities for the United States, Japan, and Germany are -0.29 to -4.78, -0.26 to -3.40, and -0.09 to -1.82.

If price elasticities are categorized by countries, then no indisputable conclusion can be made. However, as first suggested by Houthakker and Magee (1969), the income elasticities of exports and imports of a country may not be equal. If the proportion of the growth rate of exports relative to foreign income of a country is higher than the proportion of the growth rate of imports relative to domestic income, then the income elasticity of exports of this country will be greater than the income elasticity of imports. The symmetric case is also true. An abundant number of empirical studies (for example, Ueda, 1983; Goldstein and Khan, 1985; Cline, 1989; Krugman, 1989; Marquez, 1989; Lawrence, 1990; Blecker, 1992; and Hooper and Marquez, 1993) have provided further econometric evidence to support this assertion. If both price and income elasticities are simultaneously considered to explain trade balance responsiveness to changes in exchange rates and incomes (see Krugman, 1989), then a country in which the income elasticity of import exceeds that of export may still suffer trade balance deterioration after a currency devaluation, although the sum of the price elasticities of this country may be sufficiently high to satisfy the Marshall-Lerner condition. The reason for this is that when the income elasticity of imports is higher than the income elasticity of exports, then the trade balance

deterioration effect may surpass the improvement effect of the devaluation on the trade balance. Therefore, this income-elasticity effect offers an alternative explanation of the trade imbalance phenomena in Germany, Japan, Korea, Taiwan, the United Kingdom, and the United States in the past decade (Cline, 1989).

When we sort the elasticities by commodities, then both the price and income elasticities of manufactured industries are generally higher than that of nonmanufactured industries (Goldstein and Khan, 1985).

### 2.3 The Debate over the Estimation of Elasticities

Before the 1940s, economists believed price elasticities of exports and imports to be high, and thus asserted that a devaluation would improve the trade balance. However, in the 1940s a remarkable number of empirical studies claimed that the estimates of export and import price elasticities were too low to satisfy the Marshall-Lerner condition (Orcutt, 1950). The phrase “elasticity optimism” was used to symbolize the firm belief in high price elasticities of trade flows and “elasticity pessimism” to typify the view of low price elasticities of exports and imports. Nevertheless, Orcutt (1950) proposed that five biases (simultaneity, observation errors, aggregation, timing, and quantum effects) in the econometric methodology led to an underestimation of the price elasticities in the prevailing empirical literature. As a result, economists began to doubt the suitability of classical least square (CLS) econometric methodology which was believed to be the source of the low elasticity estimates. However, with the development of alternative econometric methodologies, economists’ confidence in the econometric analysis of dynamic trade modeling returned.<sup>16</sup>

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<sup>16</sup> Because Orcutt's paper (1950) encouraged people to put their energies on econometric research, Magee (1975) coined the term “Orcuttization” to refer to this trend which represented an important milestone in international trade empirical research.

Since the 1960s, most empirical results show the sum of price elasticities of exports and imports to be greater than one; that is, the Marshall-Lerner condition generally holds (Hooper and Marquez, 1993) and the “elasticity optimism” view appears to have prevailed. However, in recent years several economists (for example, Rose and Yellen, 1989; Rose, 1990 and 1991; and Mahdavi and Sohrabian, 1993) have applied modern time-series methodology and found that the exchange rate did not or only weakly influenced the trade balance. Their conclusions cast fresh doubt on the traditional economic thinking about the effectiveness of exchange rate policy on trade balance adjustment. However, Lasagabaster Latorre (1992), who also employed modern time-series analysis, found that the exchange rate did influence the trade balance in six European Community countries. Therefore, the estimates of trade studies that applied the modern time-series method provide mixed evidence about the impacts of exchange rate policy on trade balance adjustment.

Table 5 lists nine studies that applied modern time-series methodology to examine the relationship between the exchange rate and the trade balance. These studies uniformly indicate that each trade-related variable has a unit root and is nonstationary. However, their results present mixed evidence about the existence of cointegration among trade-related variables and the potential for a devaluation to improve the trade balance. Five of the nine studies demonstrated that no cointegration relationship exists between the trade balance, exchange rate, and income.

#### 2.4 The J-curve Effect

Behind the static framework, the preceding elasticity analysis implies a dynamic adjustment process whereby trade flows respond to real exchange rate changes over time. The historical experiences of other countries have shown that a depreciation of the domestic

currency may worsen the trade balance for some periods before improving it. The phrase “J-curve effect” is used to describe this phenomenon.<sup>17</sup>

One popular explanation for the existence of the J-curve effect is that the Marshall-Lerner condition does not hold in the short run but is satisfied in the long run; that is, the sum of the export and import demand price elasticities of the domestic country is lower than one in the short run, but greater than one in the long run. Thus, following a devaluation, the trade balance deteriorates since the initial demands are inelastic; however, the demand elasticities increase over time, and the trade balance eventually improves (Husted and Melvin, 1993).

Another interpretation of the J-curve effect is that if the initial trade balance deficit is significant, then the validity of the trade balance improvement condition is more difficult in the short run than in the long run. If this is so, then the J-curve effect would be the result (Buiter, 1989; Hooper and Marquez, 1993).

Empirical work on the J-curve effect are classified into two approaches: (1) the trade balance approach and (2) the import and export functions estimation approach (Moffett, 1989). The trade balance approach examines the sensitivity of trade balances to exchange rate changes. Some of these studies are those by Miles (1979), Bahmani-Oskooee (1985 and 1989), Himarios (1985), Wood (1991), Rose and Yellen (1989), Bahmani-Oskooee and Malixi (1992), Lasagabaster Latorre (1992), and Liu (1993). In the import and export functions estimation approach, the effects of exchange rate changes on trade prices and quantities are examined. Some of the studies that have taken this approach include Ahluwalia and Hernandez-Cata (1975), Bahmani-Oskooee (1986), Krugman and Baldwin (1987), Helkie and Hooper (1988), Meade (1988), Moffett (1989), and Marquez.

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<sup>17</sup> The phrase first appeared in the 1968 National Institute Economic Situation Review (N.I.E.S.R) in a discussion of the delayed trade volume response effect of the 1967 British pound devaluation (Gandolfo, 1987).

(1991). In general, the results of these studies yield mixed evidence about the existence of the J-curve effect.

## 2.5 Comparison of the Elasticity and Alternative Approaches

Over the years, alternative approaches to trade balance adjustment have been developed including the absorption and monetary approaches. Each approach focuses on a different adjustment process to explain the behaviors witnessed in the complicated real world. The elasticity approach focuses on price effects, the absorption approach concentrates on income effects, and the monetary approach is based on money demand behavior and money market equilibrium. Each individual approach captures one aspect of the general model so that every approach is, in fact, an alternative partial equilibrium model.

The elasticity approach claims that if the critical elasticity condition is satisfied (for example, the Bickerdike-Robinson-Metzler condition or the Marshall-Lerner condition), then a devaluation will improve the trade balance. This approach focuses on the components of the trade balance account and regards the trade balance as the difference between exports and imports. A trade deficit implies that the domestic country buys more goods from foreign countries than it sells, and a devaluation will affect the trade balance through the effects of relative price changes on exports and imports.

However, the absorption approach emphasizes the components of the national income and product accounts and views the trade balance as the difference between national income and domestic absorption. Thus, a trade deficit implies that domestic expenditure exceeds national income, and a devaluation influences the trade balance through the effects of exchange rate changes on domestic income and absorption. Alexander (1952) indicates that the net effects of trade balance to exchange rate changes are ambiguous. The net

effects depend on various effects of changes in exchange rate on national income and direct absorption.

According to the elasticity approach, if the Marshall-Lerner condition holds, then a devaluation will improve the trade balance. The multiplier effect introduced by absorption school writers suggests that this improvement in the trade balance will lead to an increase in domestic income. Conversely, if the Marshall-Lerner condition does not hold, then a devaluation will worsen the trade balance which, in turn, will cause a decrease in domestic income. Because growth of domestic income tends to induce an increase in imports, the sum of elasticities in the presence of income effects must be somewhat greater than the sum in the absence of income effects. Therefore, the elasticity approach and the absorption approach are complementary to one another rather than competitive.

The monetary approach focuses on analyzing the overall balance-of-payments account, while the elasticity and absorption approaches concentrate on the trade balance account. However, all three approaches are specific partial equilibrium approaches to a general equilibrium problem, and each approach can only describe a part of this broader economic system. Thus, trying to understand the economy as a whole on the basis of one approach alone may be misleading.

Recently a modern optimizing approach has developed a general equilibrium, intertemporal model that views the current account balance as the result of intertemporal choices by households between consumption in the present and future, and by firms who choose the optimal investment levels to maximize expected profits (Frenkel and Razin, 1992). These models yield a variety of devaluation adjustment outcomes depending on preference technology and the timing or permanent of a devaluation. However, formal empirical research using this approach are few (Razin, 1993).

Despite the shortcomings mentioned, the elasticity approach has been the most widely used in empirical trade studies for the past 50 years and these studies have generally

presented consistent and logical conclusions. Following this literature, this study applies the elasticity approach and compares the empirical results with those in the existing trade adjustment literature.

## CHAPTER 3

## AN EMPIRICAL MODEL OF TAIWAN'S TRADE BALANCE ADJUSTMENT

Taiwan is a natural resource–poor country and depends on international trade for its economic development. Raw materials, energy, and other intermediate inputs are imported for production of export products to foreign countries. By incorporating this relationship, this dissertation differs from previous studies in that it assumes the export supply of Taiwan to be determined not only by export price but also by imported input prices.

## 3.1 The Modified Bickerdike-Robinson-Metzler Model

In order to consider the interactive relationship between the export and import markets, where the production of export goods depends heavily on imported inputs, I modify the original Bickerdike-Robinson-Metzler model to explicitly consider the effect of import price on export supply. The revised model is referred to in this paper as the modified Bickerdike-Robinson-Metzler model and is defined as follows:

$$(17) \quad x^s = x^s(P_x, e \cdot P_m)$$

$$(18) \quad x^d = x^d\left(\frac{P_x}{e}, P^*, Y^*\right)$$

$$(19) \quad x^s = x^d = x$$

$$(20) \quad m^s = m^s(P_m, P^*)$$

$$(21) \quad m^d = m^d(e \cdot P_m, P, Y)$$

$$(22) \quad m^s = m^d = m$$

$$(23) \quad B = P_x \cdot x - e \cdot P_m \cdot m$$

where  $x$  = export quantity

$m$  = import quantity

$x^s$  = quantity of export supply

$x^d$  = quantity of export demand

$m^s$  = quantity of import supply

$m^d$  = quantity of import demand

$e$  = nominal exchange rate (i.e., units of domestic currency per unit of foreign currency)

$P$  = domestic price level

$P^*$  = foreign price level

$P_x$  = export price in terms of the domestic currency

$P_m$  = import price in terms of the foreign currency

$B$  = nominal trade balance in terms of the domestic currency

$Y$  = nominal domestic income

$Y^*$  = nominal foreign income.

Equation (17) is the export supply curve which is positively related to export price and negatively related to import price. The export demand curve, equation (18), depends negatively on export price, and positively on foreign price and nominal foreign income. Equation (19) represents the equilibrium condition in the export market. Equations (20) and (21) are the import supply curve, which depends positively on import price, and the import demand curve, which depends negatively on import price and positively on domestic price and nominal domestic income. The equilibrium condition for the import market is expressed in equation (22). Finally equation (23) shows that the nominal trade balance in terms of the domestic currency is the difference between exports and imports.

In both the original Bickerdike-Robinson-Metzler model (see Chapter 2) and the modified Bickerdike-Robinson-Metzler model presented in here, the effects of exchange rate changes on exports, imports, and the trade balance are analyzed. However, the Bickerdike-Robinson-Metzler model considers separately the export and import markets

because it assumes that these markets do not affect one another. The modified Bickerdike-Robinson-Metzler model, on the other hand, considers the interactive effects between export and import markets since changes in the import price can influence export supply.

If we assume a devaluation—that is, the exchange rate increases from  $e^0$  to  $e^1$ —then the import supply curve shifts to the left from  $S_m$  to  $S_m^1$  in Figure 22(b); this indicates that, *ceteris paribus*, foreign sellers will gain more units of the domestic currency for a given quantity of imports (though they earn the same units of the foreign currency as before the devaluation). Then the import price increases from  $P_m^0$  to  $P_m^1$  and import quantity decreases from  $m^0$  to  $m^1$ , reflecting domestic importers' unwillingness to buy the same quantities of imports at the higher import price. In Figure 22(a), the export demand curve shifts to the right, from  $D_x$  to  $D_x^1$ , indicating that, *ceteris paribus*, foreign buyers are willing to pay more units of the domestic currency than before for a given quantity of exports. When the production of export goods depends on imported inputs, then the export price is a mark-up over import price and other costs. The export supply curve will shift to the left, from  $S_x$  to  $S_x^1$ , because the increase in import price requires an export price increase for a given quantity of exports. Therefore, the export price unambiguously increases from  $P_x^0$  to  $P_x^1$ , but the change in export quantity is ambiguous.

From the two panels in Figure 22, it is apparent that the changes in exports and imports are ambiguous; thus the impacts of a devaluation on the trade balance is also ambiguous. However, from equations (17) to (23), if we assume the initial trade balance is zero, then the “modified Bickerdike-Robinson-Metzler condition” can be derived from equations (17) through (23) as:

$$(24) \quad \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} - \frac{s_l \cdot s_m \cdot (d_x - 1)}{(s_x + d_x)(s_m + d_m)} > 1$$

where  $s_I$  = import price elasticity of export supply and  $s_x$  = export price elasticity of export supply. Equation (24) is a critical elasticity condition in order for there to be a positive effect from a devaluation in the modified Bickerdike-Robinson-Metzler model.<sup>18</sup>

Equation (24) shows that the introduction of imported inputs into the production of domestic export goods may lead to the result that appreciations in the exchange rate are accompanied by improvements in the trade balance. This result can also be explained as follows. When a country's currency appreciates, then the cost of imports declines. This positive supply shock in the domestic economy reduces the cost of production, and hence export price, but raises export quantity. If this shock is significant enough, then the trade balance may improve because the gain in export revenue will exceed the loss. This supply shock consideration in the export market provides a theoretical explanation of Taiwan's slow trade balance adjustment process in the late 1980s.

In general, both the Bickerdike-Robinson-Metzler condition and the modified Bickerdike-Robinson-Metzler condition depend on the relationship between price and quantity. Elasticity measures the responsiveness of quantity to price changes. Therefore, if the volume effect exceeds the value effect after a devaluation, then the trade balance will improve.

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<sup>18</sup> If the initial trade account is unbalanced, then the modified Bickerdike-Robinson-Metzler model's condition is:

$$(24)' \left( \frac{P_x^0 \cdot x^0}{e^0 \cdot P_m^0 \cdot m^0} \right) \cdot \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} - \left( \frac{P_x^0 \cdot x^0}{e^0 \cdot P_m^0 \cdot m^0} \right) \cdot \frac{s_I \cdot s_m \cdot (d_x - 1)}{(s_x + d_x)(s_m + d_m)} > 1$$

The first and third terms of equation (24)' imply that the initial trade account may be unbalanced. When initial imports greatly exceed initial exports, then the first term of the equation indicates that a devaluation must increase exports more to offset the effect of the devaluation on the increase in import expenditure. But the third term of the equation demonstrates that it is easier to satisfy the modified Bickerdike-Robinson-Metzler condition because the supply effect is smaller than before. On the other hand, if there is initially a trade surplus, then the first term of the equation indicates that the modified Bickerdike-Robinson-Metzler condition is more easily satisfied, but, at the same time, the third term of the equation is less easily satisfied than before.

Comparing equation (8) with equation (24) shows that the difference between the Bickerdike-Robinson-Metzler condition and the modified Bickerdike-Robinson-Metzler condition is that the Bickerdike-Robinson-Metzler condition includes two independent weighted elasticity terms. In addition to these two independent weighted elasticity terms, the modified Bickerdike-Robinson-Metzler condition contains an extra term which represents the interactive effect of the import price on the export market. Therefore, it is usually more difficult to satisfy the modified Bickerdike-Robinson-Metzler condition than the Bickerdike-Robinson-Metzler condition since export demand elasticity is usually greater than one, thereby making the supply effect negative.

However, if we assume that the initial trade balance is zero and that price elasticities of both export and import supplies are infinite, then the modified Bickerdike-Robinson-Metzler condition is reduced to the Marshall-Lerner condition cited earlier:

$$(9) \quad d_x + d_m > 1.$$

If a small-country case is considered, then reasonable elasticity assumptions may be that the price elasticities of export demand and import supply are infinite (Magee, 1975). Figure 23 illustrates the effect of a devaluation on a small country. If the exchange rate increases from  $e^0$  to  $e^1$ , the import supply curve shifts up from  $S_m$  to  $S_m^1$  as foreign sellers require a higher price in terms of domestic dollars to sell a given quantity in order to maintain earnings in terms of foreign currency (Figure 23a and 23b). Therefore, import price increases from  $P_m^0$  to  $P_m^1$  and import quantity decreases from  $m^0$  to  $m^1$ . At the same time, the export demand curve shifts up from  $D_x$  to  $D_x^1$  (Figure 23b) reflecting the fact that, *ceteris paribus*, foreign consumers are willing to pay a higher price for a given quantity in terms of domestic dollars. When the production of export goods depends on imported inputs, then the export price is a mark-up of the import price. The export supply curve will shift up from  $S_x$  to  $S_x^1$  as the rise in the import price leads to export price increases for every given quantity of exports. Therefore, the export price unambiguously

increases from  $P_x^0$  to  $P_x^1$ , but the change in export quantity is ambiguous. Thus, as shown in Figure 23, the changes in exports and imports are ambiguous, and consequently, the impact on the trade balance is also ambiguous.

Using equation (24), the trade balance improvement condition from a devaluation is that the sum of the export supply elasticity and the import demand elasticity must be greater than the import price elasticity of export supply. The mathematical expression is:

$$(25) \quad s_x + d_m > s_I.$$

Equation (25) implies that a small country cannot always improve its trade balance by devaluing its currency. If imported inputs are the main factors used in the production of domestic export goods, a devaluation leads to an increase in the cost of imports. This negative supply shock to the domestic economy raises the cost of production and, hence, the export price, but reduces export quantity. If the shock is large enough, then there will result a loss in export revenue and the trade balance worsens.

The above discussion of the trade balance improvement conditions in the cases of a large country, a small country, and infinite supply elasticities for the modified Bickerdike-Robinson-Metzler model is summarized in Table 6.

### 3.2 Specification and Econometric Methodology

Referring to equations (17) and (18) in section 3.1, the export demand and supply functions can be expressed in general form as follows:

$$(17) \quad \text{Export supply function: } x^s = x^s(P_x, e \cdot P_m)$$

$$(18) \quad \text{Export demand function: } x^d = x^d\left(\frac{P_x}{e}, P^*, Y^*\right)$$

Equation (17) demonstrates that the quantity supplied of exports is not only determined by export price, but also by import price reflecting Taiwan's lack of natural resources.

Quantity demanded of export is determined by export price and foreign income (equation 18).<sup>19</sup>

If the export demand function is assumed to be homogeneous of degree zero in price and income (which implies no money illusion), then the export demand function can be rewritten as:

$$(18)' \quad x^d = x^d\left(\frac{P_x}{e \cdot P^*}, y^*\right)$$

where  $y^*$  = real foreign income and the other variables are as defined earlier.<sup>20</sup> In equation (18)',  $\left(\frac{P_x}{e \cdot P^*}\right)$  is the relative export price. Note that in this term, the divisor of export price is the foreign price level in terms of the domestic currency; this reflects substitution in consumption between domestic and foreign goods.

On the import side, it can be assumed that Taiwan cannot influence the import price since Taiwan imports a small part of the world's total imports of goods. That is, Taiwan is

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<sup>19</sup> Standard demand theory suggests that demand is a function of price and income. Income (whether it be expressed in GNP or GDP) represents the overall economic performance of a country. Therefore, in econometrics, most economists usually treat income as a proxy for economic development. If domestic income increases, then the domestic country will import more foreign goods and the domestic trade balance worsens. If foreign income increases, then the foreign country will import more domestic goods (that is, domestic country exports would increase) and the domestic trade balance improves. However, GNP and GDP are highly correlated with exports and imports since both are components of GNP and GDP. This is especially a problem when a country is a relatively small open economy, and when its export-income and import-income ratios are high. Since the trade balance is the gap between a country's exports and imports, GNP and GDP are also highly correlated with the trade balance. To address this problem, economists have looked at other variables as appropriate proxies of economic activity. For example, Krugman (1992, pp. 28–30) has suggested using expenditure. Hooper and Marquez (1993) defined economy activity to be expenditure since expenditure does not include exports and imports.

<sup>20</sup> The assumption of homogeneity is prevalent in the estimations of export and import demand functions. See, for example, Houthakker and Magee (1969), Goldstein and Khan (1978), and Rose and Yellen (1989). Of the 37 studies of price elasticity estimates that are listed in Table 1 of Hooper and Marquez (1993), 29 papers assume homogeneity constraints.

a price-taker in the import market. Therefore, the import price is determined by the world market and quantity of imports is uniquely determined by import demand.

Referring to equation (21) of section 3.1, the import demand function can be specified in a general form as follows:

$$(21) \quad \text{Import demand function: } m^d = m^d(e \cdot P_m, P, Y)$$

Assuming the import demand function is homogeneous of degree zero (implying no money illusion) in price and income, then the import demand function can be rewritten as:

$$(21)' \quad \text{Import demand function: } m^d = m^d\left(\frac{e \cdot P_m}{P}, y\right)$$

where  $y$  = real domestic income and the other variables are as defined earlier. In equation (21)',  $\frac{e \cdot P_m}{P}$  is the relative import price. Using the domestic price as the divisor of import price in terms of the domestic currency reflects substitution in consumption between domestic and foreign goods.

The above specifications only consider the general behavioral relationships and do not establish a specific functional form for the trade equations. It is standard practice in international trade modeling to use a log-linear empirical specification where the coefficients represent constant elasticities that are independent of the units for measuring the sensitivity between the economic variables.<sup>21</sup> Therefore, the log-linear forms of the export and import functions are:

$$(17)' \quad \text{Export supply function: } \ln x_t^s = a_1 + s_x \cdot \ln(P_x)_t - s_l \cdot \ln(P_m)_t + u_t$$

$$(18)'' \quad \text{Export demand function: } \ln x_t^d = a_2 - d_x \cdot \ln\left(\frac{P_x}{e \cdot P^*}\right)_t + \zeta_x \cdot \ln y_t^* + v_t$$

$$(21)''' \quad \text{Import demand function: } \ln m_t^d = a_3 - d_m \cdot \ln\left(\frac{e \cdot P_m}{P}\right)_t + \zeta_m \cdot \ln y_t + w_t$$

where  $a_1$ ,  $a_2$ , and  $a_3$  = constant terms

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<sup>21</sup> The problem with using a linear form is that the coefficients are marginal propensities and elasticities vary. However, coefficients of a log-linear form are elasticities that remain constant in the same curve if the axis is at its original level or in the same line if the axis is expressed in log terms.

$d_x$  = price elasticity of export demand

$s_x$  = export price elasticity of export supply

$s_I$  = import price elasticity of export supply

$d_m$  = price elasticity of import demand

$\zeta_x$  = income elasticity of exports

$\zeta_m$  = income elasticity of imports.

The directions of effects for responses of export supply to import price, export demand to relative export price, and import demand to relative import price are expected to be negative, while the responses of export supply to export price and the two income terms are expected to be positive. The elasticity approach suggests that a devaluation must improve the trade balance. Therefore, the effectiveness of a devaluation policy can be quantified by placing the estimated elasticities ( $d_x$ ,  $s_x$ ,  $d_m$ , and  $s_I$ ) into equation (24) which is the formula for the modified Bickerdike-Robinson-Metzler condition.

In the above analysis, focus was only given to specifying the structural form of the export and import functions. However, if we are only interested in the sign and/or magnitude of the relationship between the two variables and do not care about the structural relationship between these two variables, then the reduced form is a good alternative specification since the results can be directly estimated from the reduced equation and structural parameters do not need to be specified (Rose and Yellen, 1989).

From equations (17) to (23), the reduced form for the real trade balance function is:

$$(26) \quad b = b\left(\frac{e \cdot P^*}{P}, y, y^*\right)$$

where  $b$  = real trade balance and  $\frac{e \cdot P^*}{P}$  = real exchange rate. According to equation (26),

the real trade balance is a function of real domestic income, real foreign income, and the real exchange rate. The log-linear form of equation (26) is:

$$(26)' \quad \ln b_t = \mu + \alpha \cdot \ln\left(\frac{e \cdot P^*}{P}\right)_t + \beta \cdot \ln y_t^* + \gamma \cdot \ln y_t + \varepsilon_t$$

where  $\alpha$ ,  $\beta$ , and  $\gamma$  represent the effects of exchange rate, foreign income, and domestic income changes, respectively, on the real trade balance.

Traditional empirical trade studies analyze the effects of changes in the exchange rate, price, and income on trade flows by assuming that the level of trade flows has a stable equilibrium relationship with the exchange rate and other explanatory variables. However, the variables employed in these trade models typically follow upward or downward trends. With trending variables, standard regression equations may erroneously detect significant relationships between dependent and independent variables where, in fact, no such relationship exists (Harvey, 1990). To avoid this “spurious regression” problem, the modern time-series methodology asserts that the trended time-series data should be differenced prior to running the regression, unless a stable equilibrium “cointegrating” relationship between the dependent and independent variables exists (Hamilton, 1994).

The cointegrated series captures the long-run equilibrium relationship between the variables when these variables are trending upward together at roughly the same rate. In this case, an error correction model can be estimated that simultaneously captures both the short-run dynamic and long-run equilibrium relationships among the variables (Harvey, 1990). The coefficient of the error correction term is negative and less than one; that is, if the value of the dependent variable is greater than the combined value of the constant and independent variables in the last period, then the current period dependent variable tends to decrease to correct the discrepancy (which is treated as an error term between the previous period and the long-run equilibrium; Hamilton, 1994).

Engle and Granger (1987) suggested using a static regression as a cointegrating regression to test for the presence of cointegration. The representative cointegrating regression of trade equations (17)', (18)", (21)", and (26) would take the form:

$$(27) \quad x_t = \alpha + \beta \cdot q_t + \gamma \cdot y_t + \varepsilon_t$$

where  $x_t$  = trade flows,  $q_t$  = real exchange rate, and  $y_t$  = real income. If a cointegration relationship exists, then we can specify the error correction model of trade equations as:

$$(28) \quad \Delta x_t = \phi(x_{t-1} - \alpha - \beta \cdot q_{t-1} - \gamma \cdot y_{t-1}) + \sum_{j=0}^n \delta_j \cdot \Delta q_{t-j} + \sum_{j=0}^n \zeta_j \cdot \Delta y_{t-j} + u_t.$$

The error correction term  $(x_{t-1} - \alpha - \beta \cdot q_{t-1} - \gamma \cdot y_{t-1})$  captures the long-run equilibrium relationship among the trade variables. The lag terms in equation (28) construct a dynamic specification which reflects the time lag adjustments of exchange rate and income changes on trade flows. However, if the cointegration relationship does not exist, then the first difference model of trade equations should be specified as

$$(29) \quad \Delta x_t = \sum_{j=0}^n \delta_j \cdot \Delta q_{t-j} + \sum_{j=0}^n \zeta_j \cdot \Delta y_{t-j} + u_t.$$

A more detailed discussion of econometric estimation of equations (27)–(29) is given in Chapter 4.

## CHAPTER 4

### ECONOMETRIC ESTIMATES

#### 4.1 Introduction

In this chapter, the modern time-series method is utilized to specify and estimate the international trade flow functions derived in Chapter 3. These trade flow functions are then used to evaluate the effect of changes in the exchange rate on trade flows and their policy implications for Taiwan–U.S. and Taiwan-Japan bilateral trade.

Before deriving the estimated functions, however, the chapter reviews some important econometric issues (for example, simultaneity bias, identification, and cointegration) that have been raised regarding estimation of trade equations (see, for example, Orcutt, 1950; Goldstein and Khan, 1985; and Rose and Yellen, 1989).

#### 4.2 Econometric Issues

##### 4.2.1 Simultaneity (endogeneity) bias

Simultaneity bias is a statistical problem that violates the assumption of the CLS method that the regressors are uncorrelated with the disturbance term.

As presented earlier in Chapter 3, the export supply and export demand equations are:

$$(17) \quad \text{export supply function: } x^s = x^s(P_x, e \cdot P_m)$$

$$(18)' \quad \text{export demand function: } x^d = x^d\left(\frac{P_x}{e \cdot P^*}, y^*\right).$$

These functions represent a system of equations and may, consequently, suffer a simultaneity (endogeneity) bias problem. Thus changes in export quantities may create excess demand or supply in the foreign exchange markets and a change in the real exchange

rate may be necessary to eliminate this excess demand or supply. That is, while the real exchange rate is a key variable that affects the export quantities, the real exchange rate may also be determined by the export quantities. If equations (17) and (18)' construct a system of simultaneous equations, then both the export quantities and the real exchange rate are endogenous variables in this simultaneous equations system since they are determined simultaneously.<sup>22</sup> However, the estimators derived from the classical least square method in this system of simultaneous equations will be biased and inconsistent since the error terms are correlated with the endogenous explanatory variable, i.e., the real exchange rate.

Orcutt (1950), one of the first to cite the simultaneity bias problem, demonstrated that simultaneity between quantities and prices in trade models may lead to a downward bias in the estimated price elasticities using the classical least squares method. The rationale behind this downward bias is as follows: When the relative export price rises (that is, the real exchange rate appreciates) by one percent, foreign demand for domestic exports will fall, with the price elasticity of demand indicating by how much foreign demand declines. If there is no feedback effect between price and quantity, then there is no pressure for the price and quantity to change further. However, if such a feedback effect exists, the initial reduction in export quantity is likely to create an excess demand in the foreign exchange market. This excess demand causes the real exchange rate to depreciate; that is, there is a fall in relative export price. This fall in the relative export price will partly offset the initial negative effect of the rise in the relative export price on export quantity. Therefore, the estimated elasticity using the CLS method in the presence of an endogeneity bias may be lower than the "true" price elasticity of demand. Another expression of this question is that the estimated elasticity is a weighted average of the negative demand and positive supply

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<sup>22</sup> Although both the trade flows and the real exchange rates are endogenous variables in trade models, in this study, I follow the existing literature by estimating a partial equilibrium model rather than a full simultaneous equation system. The potential endogeneity bias problem is statistically corrected by using the Saikkonen (1991) model.

elasticities, and thus may be smaller than the “true” demand elasticity in terms of absolute value.

Several simultaneous estimation methods have been used in trade studies to deal with the endogeneity bias. For instance, Ahluwalia and Hernandez-Cata (1975) used indirect least squares (ILS); Goldstein and Khan (1978) employed full information maximum likelihood (FIML); Ueda (1983) used instrumental variables (IV); and Khan (1974) and Hooper and Marquez (1993) applied the two-stage least squares method (2SLS). However, the CLS method has been and remains the most popular approach employed with economists typically assuming away the endogeneity bias problem by analyzing a partial equilibrium demand-side model. As was mentioned in Chapter 2, this demand-side analysis follows the framework of the Keynesian approach. In Hooper and Marquez (1993, p. 30), three out of thirty-seven studies used the simultaneous-estimation method while the rest applied the CLS method; for both types of studies, it was found that the elasticity estimates are not significantly influenced by the choice of methodology employed.

Engle and Granger (1991, p. 10) claim that the simultaneous equations bias is not an important problem when a group of integrated variables are cointegrated. The reason is that when the sample size is sufficiently large, then the estimates of the coefficients are “super-consistent”; that is, the coefficients converge to their true values at a faster rate than usual. However, a considerably small sample bias may still exist (Harvey, 1990, pp. 295–296; Banerjee, Dolado, Galbraith, and Hendry, 1993, p. 176) when annual data are used in the estimation. Thus, the simultaneous equations bias may be an important problem in this study.

Fortunately, Saikkonen (1991) provided an asymptotically efficient estimation procedure in the presence of cointegration to correct for the endogeneity bias problem by including the lead, current, and lagged first difference terms of independent variables as

regressors in the cointegrating equation. Therefore, in this study, the Saikkonen (1991) approach is employed to estimate the trade equations. The Saikkonen (1991) model of trade equations can be specified as:

$$(30) \quad x_t = \alpha + \beta \cdot q_t + \gamma \cdot y_t + \sum_{j=-n}^n \delta_j \cdot \Delta q_{t-j} + \sum_{j=-n}^n \zeta_j \cdot \Delta y_{t-j} + u_t$$

where  $x_t$  = trade flows,  $q_t$  = real exchange rate, and  $y_t$  = real income.

The important idea behind the Saikkonen (1991) model is that the last period exchange rate initially influences the current period trade balance, and, in turn, the current period trade balance affects the current period exchange rate. If the feedback effect between the exchange rate and the trade balance exists, then the current period exchange rate can also influence the current period trade balance. The inclusion of lead terms in the model represents the idea that the current period trade balance will continually affect the next-period's exchange rate. The statistical purpose of the Saikkonen (1991) model is that feedback effect relationships may exist in the data; thus, if we do not correct for this endogeneity bias problem, then the estimated elasticity derived from the classical least square (CLS) method would be less than the real elasticity.

Although the Saikkonen (1991) model can correct for the simultaneity (endogeneity) bias, there remains the problem of identifying whether the estimated equations are export supply or export demand functions, i.e., an identification problem.

#### 4.2.2 Identification

Although in equations (17) and (18)' export quantity can be distinguished on the demand and supply sides, in the real world, the observed export quantity cannot be classified as a supply or demand quantity. Therefore, the identification problem of the trade equation estimation is concerned with whether we can affirm that the estimated

equation is the export demand function, the export supply function, or a linear combination of the two.

Basically, identification is a mathematical problem rather than a statistical one since the identification problem is not caused by the violation of any statistical assumption or because of the small sample property. The identification problem is a logical question that must be considered prior to undertaking any estimation (Judge, Griffiths, Hill, Lutkepohl, and Lee, 1985, p. 585).

One way to view the identification problem is to estimate the reduced-form equations, and then use the estimators of the reduced-form equations to derive the structural parameters. However, it is not always possible to do this. Therefore, whether or not the structural parameters can be deduced from the reduced-form equations is an identification problem (Kennedy, 1992, p. 152).

To check for the identification property of a equation, two conditions need to be considered: the order and rank conditions. The order condition is a necessary condition for the equation to be identified such that  $R \geq G-1$ , where  $R$  is the number of excluded exogenous variables and  $G$  is the number of included endogenous variables. The order condition states that if the equation is identified, then the number of exogenous variables excluded from this equation must be greater than or equal to the number of included endogenous variables minus one (Pindyck and Rubinfeld, 1991, p. 295).

The rank condition is a necessary and sufficient condition for identification. More specifically, the definition of the rank condition is such that the equation is under-identified if  $\text{rank}(\phi\beta) < (G-1)$ ; the equation is just-identified if  $\text{rank}(\phi\beta) = (G-1)$  and  $\text{rank}(\phi) = (G-1)$ ; and the equation is over-identified if  $\text{rank}(\phi\beta) = (G-1)$  and  $\text{rank}(\phi) > (G-1)$ , where  $\beta$  is a matrix constructed by the coefficients of the included endogenous and exogenous variables and  $\phi$  is a matrix constructed by the restriction information (Schmidt, 1976).

Many economic researchers suggest that consideration should be given to imposing restrictions on the simultaneous equations system to solve the identification problem; these restrictions may be derived from economic theory and a priori information. For example, the export supply and demand functions of the Bickerdike-Robinson-Metzler model form a structural-form equation system (see equations (1) and (2) in Chapter 2). However, both functions are underidentified. To resolve the identification problem of the price elasticity of demand estimation, many empirical trade studies assume the price elasticity of supply to be infinite; if so, the structural-form model becomes a recursive system. Export price is predetermined by the world market, and then export quantity is determined by the export price. However, as mentioned earlier in Chapter 2, the export supply elasticity may not be infinite; if so, the identification problem may still exist.

In fact, the structural-form equation system of the export demand and export supply functions presented in this study is identified because of implicit exclusion restrictions that are assumed, in particular that the export demand is not a function of import price and the export supply function is not determined by foreign income. Consistent estimates of export demand elasticity can be obtained if a change in import price shifts the export supply curve but not the export demand curve. On the other hand, consistent estimates of export supply elasticity can be obtained if a change in foreign income shifts the export demand curve but not the export supply curve.

In reviewing equations (17)' and (18)"', if for simplicity we assume  $(e \cdot P^*) = 1$  and  $a_1 = a_2 = 0$ , then the log-linear forms of the export and import functions are:

$$(17)' \quad \text{Export supply function: } \ln x_t^s = s_x \cdot \ln(P_x)_t - s_l \cdot \ln(P_m)_t + u_t$$

$$(18)''' \quad \text{Export demand function: } \ln x_t^d = -d_x \cdot \ln(P_x)_t + \zeta_x \cdot \ln y_t^* + v_t$$

This system can be written as follows:

$$\begin{bmatrix} \ln x_t & \ln(P_x)_t \end{bmatrix} \begin{bmatrix} 1 & 1 \\ d_x & -s_x \end{bmatrix} + \begin{bmatrix} \ln y_t^* & \ln(P_m)_t \end{bmatrix} \begin{bmatrix} -\zeta_x & 0 \\ 0 & s_l \end{bmatrix} = \begin{bmatrix} u_t & v_t \end{bmatrix}.$$

If we set  $\phi_1 = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}$  and  $\beta = \begin{bmatrix} 1 & 1 \\ d_x & -s_x \\ -\zeta_x & 0 \\ 0 & s_l \end{bmatrix}$ , then

$$\phi_1 \cdot \beta = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ d_x & -s_x \\ -\zeta_x & 0 \\ 0 & s_l \end{bmatrix} = \begin{bmatrix} 0 & s_l \end{bmatrix}, \text{ and}$$

$\text{rank}(\phi_1 \cdot \beta) = 1$  and  $\text{rank}(\phi_1) = 1$ . Therefore, the export demand function is just-identified.

If we set  $\phi_2 = \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix}$  and  $\beta = \begin{bmatrix} 1 & 1 \\ d_x & -s_x \\ -\zeta_x & 0 \\ 0 & s_l \end{bmatrix}$ , then

$$\phi_2 \cdot \beta = \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ d_x & -s_x \\ -\zeta_x & 0 \\ 0 & s_l \end{bmatrix} = \begin{bmatrix} -\zeta_x & 0 \end{bmatrix}, \text{ and}$$

$\text{rank}(\phi_2 \cdot \beta) = 1$  and  $\text{rank}(\phi_2) = 1$ ; again, the export supply function is just-identified.

As shown above the number of excluded exogenous variables is equal to the number of included endogenous variables minus one in both equations. The rank of the matrices constructed by the coefficients of the included endogenous and exogenous variables is also equal to the number of endogenous variables minus one in both equations. Therefore, equations (17)' and (18)" both satisfy the order and rank conditions and are just-identified; thus, there is no identification problem. The estimates of equation (17)'

represent the export supply function while the estimates of equation (18)" describe the export demand function.

Attempts to solve the simultaneity (endogeneity) bias and identification problems have stimulated the development of traditional econometrics over the past several decades. However, the concept of cointegration has recently led to enthusiastic discussions among econometricians. This is the topic of the next section.

#### 4.2.3 Cointegration

If there is a unit root in each series, then the traditional inference method may be invalid. To eliminate the unit roots, each time series must be differenced before estimating the model. However, this differencing process may lead to the loss of useful long-run equilibrium information. Fortunately, the concept of cointegration allows us to address the unit root problem with minimal loss in other information. According to the concept of cointegration, a set of nonstationary economic variables are cointegrated if the long-run equilibrium relationship between these economic variables tends to keep them moving together. That is, the individual nonstationary variables may be related with one another in a stationary linear combination. Cointegration tests examine whether such long-run equilibrium relationships are present among variables. The cointegration vectors of the double-log linear form of the equations represent long-run elasticities and can be estimated by running the potential cointegrating regressions.

The error correction model is estimated by running a regression of the first difference of the dependent variable on the one-period lagged residual, which represents the preceding period's deviation from the long-run equilibrium, and the current and lagged first differences of the independent variables, which demonstrate the impact effects of the independent variables on the dependent variable. Thus, the model is a combination of the

fundamental long-run equilibrium mechanism, a negative feedback effect from disequilibrium, and the short-run impact effects (Hendry, 1993, p. 452).

There are a number of methods for performing cointegration tests. The test procedure developed by Engle and Granger (1987) is one such method.<sup>23</sup>

Assume the following cointegrating regression:

$$(31) \quad y_t = \alpha + \beta \cdot x_t + \varepsilon_t.$$

Then, test to make sure that all dependent and independent variables are integrated of order one, that is I(1), and then run equation (31). Since the true error terms  $\varepsilon_t$  are unknown, the estimated residuals,  $\hat{\varepsilon}_t$ , are used to replace  $\varepsilon_t$ . Then the null hypothesis of no cointegration is tested by determining whether or not the residual  $\hat{\varepsilon}_t$  has a unit root.

If we believe a priori that the variables of a theoretical model are cointegrated, then it may be more relevant to test the null hypothesis of cointegration (Harris and Inder, 1994, p. 134). Park (1990) and Harris and Inder (1994) separately developed two procedures for testing the null hypothesis of cointegration, both of which use transformations of equation (31). However, the procedure by Park (1990) depends on the number of “superfluous” regressors (for example, a time trend variable and/or a time trend squared variable) in the cointegrating regression, while Harris and Inder’s (1994) procedure depends on the total number of regressors in the cointegrating regression.

Park’s (1990) variable addition procedure is as follows. Assume the cointegrating regression equation is

$$(31) \quad y_t = \alpha + \beta \cdot x_t + \varepsilon_t$$

where both  $y_t$  and  $x_t$  are I(1) and  $x_t = x_{t-1} + u_t$ . If  $y_t$  and  $x_t$  are cointegrated, then  $(1, -\alpha, -\beta)$  is the cointegrating vector. Hamilton (1994) showed that if  $\varepsilon_t$  and  $u_t$  are

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<sup>23</sup> Johansen (1988) presented a full information maximum likelihood test for the null hypothesis of no cointegration. Studies by Rose and Yellen (1989), Rose (1990 and 1991), and Hsing (1993), which are repeatedly cited in this study, used the computationally simpler Engle-Granger two-step procedure.

serially correlated, then the cointegrating vector cannot be obtained using CLS. One approach to get rid of this serial correlation is to transform the regression.

The first step of the transformation is to run CLS on equation (31); then measure the effects of correlation between  $\varepsilon_i$  and  $u_i$ . In the second step, the effects of the correlation is eliminated using the transformed cointegrating regression

$$(32) \quad y_i^* = \alpha' + \beta' \cdot x_i^* + \varepsilon_i^*$$

where  $y_i^* = y_i - a$ ,  $x_i^* = x_i - b$ ,  $a$  and  $b$  are the effects of the correlation, and  $(1, -\alpha', -\beta')$  is the normalized cointegrating vector.

Lasagabaster Latorre (1992, p. 103) noted that “in the absence of cointegration, the errors are nonstationary, the regression becomes spurious and the test cannot detect the insignificance of the added regressors. In the presence of cointegration, the errors are stationary and the test is able to reveal the insignificance of the added regressors.” If we add time polynomials into equation (32) as “superfluous” regressors, then the augmented transformed regression model is as follows:

$$(33) \quad y_i^* = \alpha'' + \beta'' \cdot x_i^* + \sum_{k=1}^q \gamma_k \cdot t^k + \varepsilon_i^*$$

The Park (1990) test for the null hypothesis of cointegration is based on a  $\chi^2$  statistic which is constructed from the residual sum of squares of equations (32) and (33). The degree of freedom of this  $\chi^2$  statistic depends on the number of “superfluous” regressors. If the  $\chi^2$  statistic is greater than the critical value, then the null hypothesis of cointegration is rejected; on the other hand, if the  $\chi^2$  statistic is less than the critical value, then we can conclude that the null hypothesis of cointegration cannot be rejected.

The testing procedure developed by Harris and Inder (1994) is similar to that developed by Park (1991). In this procedure, the first step is to run CLS on equation (31) also, then the estimated residuals  $\hat{\varepsilon}_i$  and  $u_i$  are used to measure the effects of correlation. However, the Harris and Inder (1994) method differs from that of Park (1990) in that it

only transforms the dependent variable and estimates the residuals terms to eliminate the effects of correlation and form a transformed regression as follows:

$$(34) \quad y_i^* = \alpha' + \beta' \cdot x_i + \varepsilon_i^*$$

where  $y_i^* = y_i - a$ ,  $a$  is the effect of correlation, and  $(1, -\alpha', -\beta')$  is the normalized cointegrating vector. Equation (34) is then reestimated to obtain the estimated residuals to construct a statistic for testing the null hypothesis of cointegration. If the statistic exceeds the critical value (tabulated by Harris and Inder, 1994), then the null hypothesis is rejected. On the other hand, if the statistic is smaller than the critical value, then the null hypothesis cannot be rejected.

If the null hypothesis of no cointegration cannot be rejected and the null hypothesis of cointegration is rejected, then this evidence strongly supports the conclusion of no cointegration. On the other hand, if the null hypothesis of no cointegration is rejected and the null hypothesis of cointegration cannot be rejected, then there is strong evidence of cointegration. However, if both the null hypothesis of no cointegration and the null hypothesis of cointegration are accepted or both null hypotheses are rejected, then we cannot draw any definite conclusion since the true data-generating processes are typically unknown.

If a cointegration relationship does not exist, it implies that the integrated variables lack a stable, long-run relationship. In this case, many economic time-series researchers recommend using the model in first differences to avoid the “spurious regression” problem of nonstationary data. However, if a cointegration relationship does exist, then the error correction model is useful in capturing long-run equilibrium information and short-run dynamic structure by including both the levels of variables and their first differences.

#### 4.3 Results of the Estimation

In this section, the results of the unit root and cointegrating tests are presented. Estimates of the structure and the reduced-form equations of trade are reported, and the implications of these empirical results are discussed.

#### 4.3.1 Testing for unit roots

Since Nelson and Plosser (1982) first used the unit root test and found that most U.S. data is nonstationary, the unit root test has become a standard diagnostic process in modern time-series analysis (Dickey and Rossana, 1994, p. 325). The economic meaning of a time series with unit root is that any shock to the time series will have a permanent effect through time because the time series has a long memory; that is, past and current shocks have identical weights in determining the current level of the time series (Engle and Granger, 1991, pp. 2–3).

A time series with unit root depends on time. One example is the New Taiwan dollar which depreciated in the early 1980s and then appreciated in the late 1980s. During this decade, nominal and real GNP clearly followed an upward trend, and export quantity and U.S. real GDP also followed upward trends. In the same time period, the relative export price showed no specific monotonic tendency but, in fact, persistently appreciated and then depreciated without any equilibrium value (see Enders, 1995, pp. 136–137). Because it is not clear as to whether the growth of GNP is “trend” or “difference” stationary, the discussion of formal unit root tests is necessary.

Before applying formal unit root test analysis, it is useful to visually inspect the correlogram of the time series.<sup>24</sup> The correlograms of trade-related variables are shown in Figures 24 through 55. These figures show that most variables in terms of level have long-

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<sup>24</sup> A correlogram is a graph that plots the estimated autocorrelations against their corresponding lags. For a stationary variable, the correlogram should decay quickly as lag length increases. Conversely, if the correlogram has a long tail, then the variable may be nonstationary and has at least one unit root.

tailed correlograms and are, thus, potentially nonstationary. However, almost all of the correlograms of the first-differenced variables decay quickly indicating that the first-difference terms of these trade-related variables are stationary.

The augmented Dickey-Fuller test is one that is widely used to test for unit root (Dickey and Fuller, 1981). The test is performed by estimating the following three equations which specify three sets of null hypotheses, depending on the presence of a constant and/or a time trend term:

$$(35) \quad \Delta y_t = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$$

$$(36) \quad \Delta y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$$

$$(37) \quad \Delta y_t = \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$$

where  $y_t$  is the relevant time series and  $u_t$  is the disturbance term. When the estimated  $t$ -value of  $\gamma$  is less than the critical value, then the null hypothesis of a unit root cannot be rejected and this indicates that  $y_t$  is nonstationary.

The distribution of the augmented Dickey-Fuller test statistic is asymmetric about the mean because it is skewed to the right; that is, it has a long tail in the right direction. Therefore, the critical values of the student- $t$  distribution is not satisfied in the augmented Dickey-Fuller test. Fortunately, Fuller (1976, p. 373, Table 8.5.2) and MacKinnon (1991) provided asymptotic critical values in their Monte Carlo experiments.

Hundreds of papers have presented their results of the augmented Dickey-Fuller test, but many arbitrarily chose constant and/or time-trend terms in estimating the regressions since the true data-generating processes are unknown. However, Campbell and Perron (1991) demonstrated that misspecification of the unit root test regression may cause the error of rejecting the null hypothesis of a unit root when, in fact, it is true (i.e., type I error). In response, Holden and Perman (1994, pp. 62–66) and Enders (1995, pp.

256–258) have suggested their own sequential procedures of the augmented Dickey-Fuller test for unit root.

Using Enders' (1995) sequential procedure (see Figure 56), the augmented Dickey-Fuller test for the trade-related variables was employed as follows. The lag length was selected using the Akaike information criterion (AIC) and the equations were then estimated. In summary, the stationarity properties of trade balances, export quantity (Taiwan-Japan), import quantities, unit value of exports, unit value of imports, and Japan and U.S. real GNP are relatively difficult to determine, while the stationarity properties of Taiwan GNP, relative import price, export quantity (Taiwan–U.S.), relative export price, and real exchange rate are unambiguous. Details of the procedure are reported as follows.

Column (3) of Table 7 reports the estimated results of equation (35). The null hypothesis is that the series has a unit root, a constant term, and a deterministic trend (i.e.,  $H_0: (\alpha_0, \alpha_2, \gamma) = (\alpha_0, \alpha_2, 1)$  versus  $H_A: (\alpha_0, \alpha_2, \gamma) \neq (\alpha_0, \alpha_2, 1)$ ). The corresponding critical values were taken from MacKinnon (1991). The export and import quantities, trade balances, and real incomes show an upward trend, and are therefore candidates for this test, while other variables do not have upward trend and, therefore, are not tested here. The t-values of the export and import quantities, trade balances, and real incomes are all smaller than the critical value at the 5% significance level. Therefore, we cannot reject the null hypothesis. However, the power of this unit root test may have been reduced by including some dispensable nonstochastic explanatory variables (for example, constant and/or time-trend terms). It is therefore necessary to check for the problem of redundant deterministic regressors.

Now let us assume the null hypothesis of a series with a unit root with no time trend (i.e., given  $\gamma = 1$ ,  $H_0: (\alpha_0, \alpha_2) = (\alpha_0, 0)$  versus  $H_A: (\alpha_0, \alpha_2) \neq (\alpha_0, 0)$ ). In this case, the corresponding critical values were taken from Dickey and Fuller (1981, p. 1062). Column (4) of Table 7 shows that the t-values of the time trends of export and

import quantities, trade balances, and real incomes are all smaller than the critical value at the 5% significance level. Therefore, we cannot reject the null hypothesis that the coefficients of the time trend terms are equal to zero. These results support the notion that the time trend is not included in the data-generating process. I therefore drop the time-trend term from the regression equation and run equation (36). The null hypothesis is that the series has a unit root and a constant term (i.e.,  $H_0: (\alpha_0, \gamma) = (\alpha_0, 1)$  versus  $H_A: (\alpha_0, \gamma) \neq (\alpha_0, 1)$ ) and the corresponding critical values are from MacKinnon (1991).

Column (5) of Table 7 shows that the t-values of all trade-related variables are smaller than the corresponding critical values at the 5% significance level. Therefore, we cannot reject the null hypothesis. However, it is also necessary to check whether or not the constant term is redundant in the regression. Therefore, the null hypothesis is a unit root with no constant term (i.e., given  $\gamma = 1$ ,  $H_0: (\alpha_0 = 0)$  versus  $H_A: (\alpha_0 \neq 0)$ ). The corresponding critical values were taken from Dickey and Fuller (1981, p. 1062).

Column (6) of Table 7 shows that the t-statistics in absolute value terms of the constant term of the export quantity (Taiwan–U.S.), trade balances (Taiwan–U.S. and Taiwan–Japan), and Taiwan real GNP are greater than the corresponding critical values at the 5% significance level. Therefore, the null hypothesis that the coefficients of constant terms are equal to zero can be rejected. In addition, the absolute value of the t-statistic for Taiwan real GNP in column (5) is found to be smaller than the corresponding critical value at the 5% significance level (standard t-value). Therefore, we can conclude that Taiwan's real GNP is a random-walk with drift variable. Although the t-statistic for the export quantity (Taiwan–U.S.) in column (5) is greater than the critical value at the 5% significance level (standard t-value), the correlogram of export quantity (Taiwan–U.S.) decays slowly (Figure 38) suggesting that the export quantity (Taiwan–U.S.) is

nonstationary. Therefore, export quantity (Taiwan–U.S.) is believed to be a variable of random-walk with drift.

As mentioned above, the stationarity properties of trade balances are difficult to determine. The t-statistics for the trade balance (Taiwan–U.S. and Taiwan-Japan) variables are greater than the critical values at the 5% significance level. This suggests that Taiwan's trade balances are stationary. However, the correlogram of trade balances (Taiwan–U.S. and Taiwan-Japan in Figures 36 and 46) do not unambiguously support this conclusion.

In checking for a unit root of trade balances (Taiwan–U.S. and Taiwan-Japan), the t-statistics of the trade balances (Taiwan–U.S. and Taiwan-Japan) are found to be smaller than the critical values at the 5% significance level (column 7 of Table 7), indicating that the trade balances (Taiwan–U.S. and Taiwan-Japan) may also be variables of random walk without drift. Therefore, it is not clear whether the trade balance (Taiwan–U.S. and Taiwan-Japan) variables are stationary or nonstationary because the unit root test do not support a clear conclusion.<sup>25</sup> However, as presented in Chapter 1, during the research period of my study, it appears that Taiwan's trade balance with the United States and with Japan show no equilibrium value; therefore, it is more likely that Taiwan's trade balances are nonstationary and variables of random-walk without drift.

Column (6) of Table 7 shows that the t-statistics of the constant terms of the export quantity (Taiwan-Japan), import quantities (Taiwan–U.S. and Taiwan-Japan), unit value of exports, unit value of imports, relative export and import prices, real exchange rate, and Japan and U.S. real GNP are smaller than the critical values at the 5% significance level. The corresponding critical values were taken from Dickey and Fuller (1981, p. 1062). Therefore, we cannot reject the null hypothesis that the coefficients of the constant terms in these cases are equal to zero.

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<sup>25</sup> Meade (1992) demonstrated that the U.S. trade balance may or may not have a unit root.

These results suggest that the constant term is not included in the data-generating process for these variables. Therefore, we can drop the constant term from the regression equation and run equation (37), assuming a null hypothesis of a unit root without a constant term. Column (7) of Table 7 shows that the t-values of the export and import relative prices and real exchange rates are smaller than their critical values at the 5% significance level; thus, the null hypothesis of a unit root cannot be rejected in the cases of export and import relative prices and real exchange rates. We conclude that export and import relative prices and the real exchange rate are variables of random-walk without drift.<sup>26</sup> However, column (7) of Table 7 also shows that the export quantity (Taiwan-Japan), import quantities (Taiwan-U.S. and Taiwan-Japan), unit value of exports, unit value of imports, and Japan and U.S. real GNP have extremely positive t-values and again their correlograms decay slowly (Figures 24, 26, 30, 32, 40, 48, and 50); thus, they appear to be nonstationary.<sup>27</sup> Other studies have also concluded that GNP is nonstationary (see, for example, Nelson and Plosser, 1982; Stock and Watson, 1988; and Hamilton,

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<sup>26</sup> If the real exchange rate actually exhibits a stationary behavior but is interrupted by large infrequent shocks, then even though the real exchange rate is stationary within each of the subperiods, a misleading inference could potentially happen. Perron (1989) developed a formal procedure to test for unit root in the presence of a structural change at a particular point in time. However, Rose and Yellen (1989), Rose (1990, 1991), Hsing (1993), and Hamilton (1994) found that the real exchange rate is I(1) and their findings support the nonstationary exchange rate property of my study. "The economic interpretation is that real productivity and/or demand shocks have had a permanent influence on real exchange rates" (Ender, 1995, p. 237). However, if the time-series properties of the data are not correctly identified, then the results may be spurious. Therefore, it is necessary to be careful about the determination of stationarity of each data series. For instance, if the trade balance is stationary and the real exchange rate is nonstationary or vice versa, then statistically we can expect to see the coefficient terms to be biased toward zero, and the equation will not tell us anything about the trade relationship. In this case, the first-difference model is the model that we must rely on.

<sup>27</sup> The roots of these variables are greater than one implying that the economic system is unstable and does not have an equilibrium. The case of  $|y| > 1$  is unreasonable because it makes no sense that the further the period is in the past, the larger is the weight of the value of that past period determines the value current period of the series  $y_t$ .

1994). Therefore, the problem here appears to be that we have unwisely excluded the constant terms from the values of column (6). If the constant terms are nonzero, we can then conclude that the export quantity (Taiwan-Japan), import quantities (Taiwan-U.S. and Taiwan-Japan), unit value of exports, unit value of imports, and Japan and U.S. real GNP are random-walk with drift variables.

As column (8) in Table 7 shows, almost all the t-values of the first-difference terms of the trade-related variables are greater than their critical values at the 5% significance level, exceptions are Taiwan's real GNP and Japan's real GNP. This suggests that almost all of the first-difference terms of variables are stationary (except for Taiwan's real GNP and Japan's real GNP). However, the correlograms of the first-difference terms of Taiwan's real GNP and Japan's real GNP decay quickly (Figures 25 and 29), suggesting that the first-difference terms of Taiwan's real GNP and Japan's real GNP are also stationary, so that all the first-difference terms of the trade-related variables are stationary, indicating that the trade-related variables are not integrated of order two. Therefore, as summarized in Table 8, all trade-related variables appear to have unit roots and be integrated of order one. Consequently, in next section I will examine whether any cointegrating relationship exists among these variables.

#### 4.3.2 Testing for cointegration

In this section, cointegration tests for the international trade equations derived in Chapter 3 are conducted using the procedures developed by Engle and Granger (1987), Park (1990), and Harris and Inder (1994). Eight equations are tested for cointegration. As the third column in Table 9 shows, with the exception of the Taiwan-U.S. import demand equation, the Engle and Granger (1987) cointegration test indicates that the other seven Taiwan trade flow equations are not cointegrated at the 5% significance level. However, the fourth column shows that, with the exception of the Taiwan-Japan trade balance

equation, the other seven equations are cointegrated at the 5% significance level using Park's (1990) method. In the last column, the Harris and Inder (1994) cointegration test indicates that all eight equations are cointegrated at the 5% significance level.

If the null hypothesis of no cointegration and the null hypothesis of cointegration are accepted in each equation, then the results of the cointegration tests are inconclusive. A plot of residuals of the cointegrating regressions and their correlograms confirm the ambiguous results of the above cointegrating tests (see Figures 57-72). This is so because the residuals of the cointegrating regressions are found to be around zero, but only infrequently cross zero; moreover, their correlograms decay moderately. Therefore, the error correction, Saikkonen (1991), and first-difference models are used to estimate Taiwan's international trade equations since the error correction and Saikkonen (1991) specifications are appropriate in the presence of cointegration, while the first-difference model represents the appropriate model in the absence of cointegration.

#### 4.3.3 Structural equation estimation results

The export demand, export supply, and import demand equations for Taiwan-U.S. and Taiwan-Japan bilateral trade were estimated using annual data for the period 1965-1994. The cointegrating regression, error correction, first-difference regression, and Saikkonen (1991) models are all used because each model has its own specific estimation purpose. The cointegrating regressions can estimate the cointegrating vectors which represent the long-run equilibrium elasticities of the double-log form equations; the error correction models combine the presence of the cointegrating relationship, a feedback effect from the preceding period's disequilibrium, and the short-run impact effect of the difference terms; the first-difference models is appropriate in the absence of cointegration; and the Saikkonen (1991) model corrects for endogeneity bias. In all models, the variables are expressed as log values. Point estimates and t-statistics are reported. The critical

values are selected using a 5% significance level and the lag lengths are selected using the Akaike's information criterion (AIC).

#### 4.3.3.1 U.S. demand for Taiwan's exports

The estimated results of equation (38.1) in Table 10 show that the estimated long-run equilibrium price elasticity of export demand is -0.981 and the income elasticity of export demand is 2.894. These imply that a one percent rise in the export price induces about a one percent decline in export quantity, but a one percent increase in income will lead to an almost three percent rise in export quantity.<sup>28</sup>

The estimated results of equation (38.2) in Table 10 show a coefficient on the error correction term of -0.104; this implies that only 10 percent of the disequilibrium value may be eliminated in the first year, a very slow pace of adjustment to equilibrium values. The short-run dynamic representation includes both contemporaneous and lagged difference terms of the relative export price but only includes the current difference term of real income. The estimated short-run price elasticity of export demand is -0.207, but the coefficient is insignificant in the current period; the estimated short-run price elasticity of export demand is -0.660 and significant in the lagged period. Income elasticity of export demand is 2.387 and significant. These relatively low short-run price elasticities imply that real income will dominate the export quantity changes in the first year.

In comparing the estimated short-run elasticities with their long-run counterparts, we may discern that both short-run price and income elasticities are lower than their long-run values. This implies that U.S. demand for Taiwan exports tend to be less sensitive to exchange rate changes and U.S. income changes in the short-run than in the long-run.

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<sup>28</sup> In cointegration analysis, it is customary to view all variables as endogenous. In my interpretation, focus is on the effects of exchange rate changes on the trade balance, whereas the Saikkonen procedure adjusts for the potential endogeneity bias.

As was noted earlier, whether there exists cointegration is unknown. If the real world does not have cointegration, then the error correction model is not appropriate and the first-difference model must be used. Similar to the error correction model, both the contemporaneous and lagged difference terms of relative export price are included in equation (38.3), but only the current difference term of real income is included. The estimated short-run price elasticity of export demand is insignificantly different from zero in period  $t$ , but is significantly different from zero in period  $t-1$ . The income elasticity of export demand is 2.165 and significant. All of the short-run estimated elasticities of this model tend to be lower than their long-run counterparts, but are similar to the estimated short-run elasticities in the error correction model.

Equation (38.4), i.e. the Saikkonen (1991) model, provides an asymptotically efficiency estimation to correct for the endogeneity bias problem in the presence of cointegration. The estimated long-run equilibrium price elasticity of export demand derived from this model is -1.747 and the income elasticity of export demand is 2.571. Using a procedure developed by Hamilton (1994, pp. 610–611), the biased CLS  $t$  statistics can be transformed to yield ordinary  $t$  statistics. The standardized  $t$  statistics for the coefficients of  $LPX_t$  and  $LUSGNP_t$  are -2.596 and 5.454, respectively, and are greater than the 5% critical value of 1.704 in absolute value.<sup>29</sup> Therefore, we can conclude that the coefficients of  $LPX_t$  and  $LUSGNP_t$  are significantly different from zero, suggesting that the relative export price and U.S. real GNP may influence export quantity.

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<sup>29</sup> The transformation formula of the standardized  $t$  statistic is  $\left( t \cdot \left( s / \tilde{\lambda}_{11} \right) \right)$ . Here  $t$  is the CLS  $t$  statistic and  $s$  is the standard error of the CLS regression. A consistent estimate of  $\tilde{\lambda}_{11}$  is  $\hat{\lambda}_{11} = \hat{\sigma}_1 / \left( 1 - \hat{\phi}_1 - \hat{\phi}_2 - \dots - \hat{\phi}_p \right)$ , where  $\hat{\sigma}_1$  and  $\hat{\phi}_i$ ,  $i = 1, 2, \dots, p$  are the standard error and coefficients of the  $p$ -th autoregression of the sample residuals.

Comparing equation (38.4) with equation (38.1), the estimated price elasticity of the Saikkonen (1991) model is much greater than its counterpart in the cointegrating regression. This is consistent with the existence of an endogeneity bias in the cointegrating equation. The reason is that, as mentioned earlier in section 4.2.1, the elasticity estimated by the CLS method in the presence of an endogeneity bias would be smaller than the true value. Therefore, the endogeneity bias correction model suggested by Saikkonen (1991) would result in a larger estimated elasticities than would the cointegrating regression model.<sup>30</sup>

Moreover, the equations take into account the argument made by Goldstein and Khan (1985) that changes in a supply factor over time may not be captured in the specifications of newly industrializing countries' export functions. In the case of Taiwan, the percentage of industrial products in Taiwan's total exports may capture an important trend in the evolution of export supply. This percentage reflects the diminishing marginal rate which is consistent with the time-series characteristics of export quantity and trade balance in Taiwan–U.S. bilateral trade. This implies that Taiwan's degree of industrialization gradually increased over time. In this study, this percentage is represented by AIP.

#### 4.3.3.2 Taiwan's export supply to the United States

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<sup>30</sup> The Q statistic of the cointegrating regression model (equation (38.1)) is 21.94 which is greater than the critical value of 14.07 of  $\chi^2$  distribution with 7 degrees of freedom at the 5% significance level. Therefore, the null hypothesis of white noise disturbances is rejected; that is, the disturbances may be serially correlated. This implies that misspecification may exist and so some caution should be taken in interpreting the results of the regressions. The Q statistics of equations (38.2)–(38.4) are smaller than the critical values, indicating that there is no evidence of serial correlation of residuals in these regressions. Similar potential equation misspecification problems generally appear in the cointegrating regression model equations for other trade flows, as reported below.

This section employs the same procedure used in the last section to estimate four versions of the equation for Taiwan's export supply to the United States. The results of equation (39.1) in Table 11 find an estimated long-run price elasticity of export supply of 4.269 and an import price elasticity of export supply of -2.378. These results suggest that a one percent rise in export price would induce a more than four percent increase in the quantity of export supply, but a one percent increase in import price would result in only a two percent reduction in export supply quantity. At first, these estimated export supply elasticities may appear to be extremely high.<sup>31</sup> However, Goldstein and Khan (1978) estimated export supply elasticities ranging from 1.1 to 6.6. Therefore, the export supply elasticities derived and shown in Table 11 are consistent with the results of Goldstein and Khan (1978), but are on the high side.

In equation (39.2), the coefficient of the error correction term is -0.336, implying that roughly 30 percent of the adjustment is completed in the first year. This is a relatively moderate pace of adjustment to equilibrium values.

In comparing the estimated short-run elasticities with their long-run counterparts, I find that the short-run price and income elasticity estimates are lower than their long-run values. Similarly, all estimated short-run elasticities of the first difference model (equation (39.3)) are smaller than their long-run counterparts; nevertheless, the elasticities derived are similar to those obtained from the error correction model.

In the Saikkonen (1991) model (equation (39.4)), the standardized *t* statistics for the coefficients of  $LUVEX_t$  and  $LUVIM_t$  are 4.610 and -3.957, respectively, and are greater than the 5% critical value of 1.704. Therefore, both the estimated long-run export

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<sup>31</sup> One possible explanation for these high estimates of export supply elasticities is that multicollinearity exists between the unit value of exports and the unit value of imports which have a common trend and tend to move together. The CLS estimator will be biased in the presence of multicollinearity (Kennedy, 1992, p. 258). The correlation between the unit value of exports and the unit value of imports is found to be 0.95. Therefore, we should be cautious in interpreting these elasticity estimates.

price elasticity of export supply and the estimated import price elasticity of export supply are significantly different from zero, supporting the notion that the export and import prices may influence the quantity of export supply.

A comparison of equation (39.4) and equation (39.1) shows that both the estimated export price and import price elasticities of the Saikkonen (1991) model tend to be smaller than their counterparts derived from the cointegrating regression.

#### 4.3.3.3 Taiwan's import demand from the United States

The estimated results of equation (40.1) are shown in Table 12. The long-run price and income elasticities of import demand were estimated to be -1.049 and 1.288, respectively. This indicates that a one percent change in import quantity results from a one percent change in price or income.

The coefficient of the error correction term in equation (40.2) is -0.422, indicating that about 40 percent of the disequilibrium will be eliminated in the first year. The low short-run price elasticities suggest that price may only influence the import quantity over time. The change in the signs of the short-run price elasticity coefficients further suggest the existence of a J-curve effect. That is, when the Taiwan currency depreciates, import quantity increases in the first year but decreases thereafter. The short-run price elasticity estimates is lower than its long-run counterpart, but the opposite is true for the income elasticity.

In the first-difference model (see equation (40.3)), the estimated short-run price elasticities tend to increase over time, again supporting the result that price plays a more important role in influencing import quantity over time.

In equation (40.4), i.e., the Saikkonen (1991) model, the standardized  $t$  statistics for the coefficients of  $LPM_t$  and  $LUSGNP_t$  are -3.820 and 29.827, respectively; which again are greater than the 5% critical value of 1.704. Therefore, the estimated long-run

price and income elasticities of import demand are significantly different from zero, suggesting that both the relative import price and Taiwan's real GNP influence import quantity.

Comparing the estimates derived from equation (40.4) with those from equation (40.1), it is clear that the estimated price elasticity of the Saikkonen (1991) model is higher, but the estimated income elasticity is slightly lower than their counterparts in the cointegrating regression.

As Tables 10 and 12 show, the estimated income elasticities for export demand of Taiwan with the United States is much higher than the estimated income elasticities for imports. This difference in income elasticities implies that Taiwan's income would have to grow about 2.5 times as fast as that of U.S. income in order to maintain a bilateral trade balance for any given real exchange rate. These estimates support the conventional view of Houthakker and Magee (1969) that the income elasticities of exports and imports of a country may be unequal (this was mentioned earlier in Chapter 2). As Table 13 shows, these estimates are similar to those of previous studies (see for example, Sheu, 1973; Cline, 1989; Moreno, 1989) that estimated Taiwan's trade equations and were concerned with the traditional view of Houthakker-Magee. Goldstein and Khan (1985) noted that newly industrializing countries' export demand functions omit an important supply factor that is positively related to income. They find that consideration of this supply factor can reduce the income elasticity by a significant degree, but does not strongly influence the price elasticity. In the Taiwan-U.S. trade case, as mentioned earlier in section 4.3.3.1, the share of Taiwan's industrial goods exports to total exports may capture an important trend in export supply expansion and represent Taiwan's industrializing degree so it may explain the shape of the quantity of Taiwan's exports to the U.S.

#### 4.3.3.4 Japan's demand for Taiwan exports

Until now, the focus of the trade equation estimates has been on the Taiwan–U.S. bilateral trade relationship. I now turn to examining Taiwan-Japan trade.

A comparison of the estimates in Tables 10 and 14 reveals that both the long-run and short-run price elasticities of U.S. demand for Taiwan exports are found to be greater than those of Japan's demand for Taiwan exports. This implies that Japan's demand for Taiwan exports may be less sensitive to exchange rate changes. A possible explanation for this is the different composition of trade between Taiwan and the United States and Taiwan and Japan. As was shown earlier (Table 1), Taiwan exports to the United States are mostly manufactures with about one-half taken up by machinery and electrical equipment. In contrast, agricultural products account for 30 percent of Taiwan's exports to Japan with meat being the largest single export item. As mentioned in Chapter 2, manufactured exports generally have higher price elasticities than nonmanufactures. Therefore, it would not surprise us to find that the total price elasticity of U.S. demand for Taiwan exports is greater than Japan's demand for Taiwan exports.

The coefficients of the time lag terms suggest a broad J-curve effect in Taiwan–U.S. trade; that is, coefficients do not change in sign but increase over time. In contrast, a normal J-curve effect appears to characterize Taiwan-Japan trade as the coefficients not only change their sign but also increase over time.

The estimated income elasticity of U.S. demand for Taiwan exports also is larger than that of Japan. This indicates that exports of Taiwanese goods to the United States may rise at a faster rate than Taiwanese goods destined for Japan, when the real incomes of both the United States and Japan increase by one percent.

The absolute value of the coefficient of the error correction term in equation (38.2) is smaller than that of equation (41.2); that is, the speed of adjustment in U.S. demand for Taiwan exports to the equilibrium value is found to be relatively slower than that in the Taiwan-Japan case.

#### 4.3.3.5 Taiwan's export supply to Japan

As shown in Table 15, the estimated long-run export price and import price elasticities of export supply are extremely high. As mentioned earlier in section 4.3.1.2, the presence of multicollinearity between export prices and import prices is one possible explanation for these results.

A comparison of the estimates in Table 11 and Table 15 reveals that for both the long run and the short run, the estimated export price and import price elasticities of Taiwan's export supply to Japan are greater than that of the Taiwan-U.S. case. That is, Taiwan's export supply to Japan appears to be more sensitive to export price and import price changes than is its export supply to the United States.

The absolute value of the coefficient of the error correction term in equation (42.2) is greater than that of equation (39.2), leading one to conclude that the speed of adjustment in Taiwan's export supply to Japan to its equilibrium values is relatively faster than is that for Taiwan's export supply to the United States.

#### 4.3.3.6 Taiwan's import demand from Japan

The estimated long-run price elasticity of Taiwan's import demand from the United States is greater than that of Taiwan's import demand from Japan (see Tables 12 and 16), implying that Taiwan's import demand from Japan may be less sensitive to exchange rate changes. Again, differences in the composition of trade between Taiwan and the United States and Taiwan and Japan trade may explain this observation. Although Table 1 shows that Taiwan's imports from the United States and Japan are both mostly manufactures, the type of manufactured goods coming from these two countries are quite different. Most imports from Japan are semi-manufactured products such as durable consumer and capital goods (World Journal, 1995). In contrast, a significant proportion of Taiwan's imports

from the United States are final (finished) manufactures including nondurable consumer goods. Because the price elasticity of final (finished) manufactures is generally much higher than that of semi-manufactures (Houthakker and Magee, 1969, p. 121), it is no surprise to find the total price elasticity of Taiwan's import demand from the United States to be greater than that of Taiwan's import demand from Japan.

The estimated short-run price elasticities show that Taiwan's import demands from both the United States and Japan appear to follow a normal J-curve pattern in the error correction model; but broad J-curve effects are found from the first-difference model.

The estimated income elasticity of Taiwan's import demand from the United States is similar to that of Japan. Thus, the quantity of Taiwan imports from the United States is predicted to expand at a similar rate as do its imports from Japan when the real income of Taiwan increases by one percent.

The coefficient of the error correction term in equation (40.2) is slightly lower than that of equation (43.2). Therefore, the speed of adjustment in Taiwan's import demand from the United States to its equilibrium value appears to be relatively slow compared to the Taiwan-Japan case.

#### 4.3.4 The reduced-form equation estimation results

If we are interested in predicting the endogenous variable, estimating the effect of exogenous variables on the endogenous variable, and comparing the estimated results with those of recent modern time-series studies surrounding trade balance adjustment (for example, Rose and Yellen, 1989; Rose, 1990 and 1991; Lasagabaster Latorre, 1992), then it is necessary to estimate the reduced-form versions of the trade equations.

The trade balance functions of Taiwan-U.S. and Taiwan-Japan bilateral trade were estimated by using annual data for the period 1965-1994. The cointegrating regression,

error correction, first difference regression, and Saikkonen (1991) models are applied for particular estimation purposes.

#### 4.3.4.1 The trade balance of Taiwan with the United States

For equation (44.1), the estimated long-run elasticities with respect to the real exchange rate, foreign income, and domestic income are 1.856, 1.470, and -0.612, respectively (Table 17). Considering the size of existing imbalances, the real exchange rate elasticity estimate of 1.856 suggests that to eliminate Taiwan's trade surplus with the United States, a currency appreciation of about 53.88 percent would be necessary.

In equation (44.2), the coefficient of the error correction term, -0.316, implies that a 30 percent disequilibrium would be eliminated in the first year, a relatively moderate speed of adjustment.

Comparing the estimated short-run and long-run elasticities, I find that the short-run elasticities with respect to the real exchange rate and Taiwan's real GNP are lower than their long-run values, but the elasticity with respect to U.S. real GNP is slightly higher than its long-run value.

In the Saikkonen (1991) model, the estimated long-run elasticity with respect to the real exchange rate is significantly different from zero, but the elasticity with respect to U.S. real GDP and Taiwan real GNP are not significantly different from zero. These estimates support the conclusion that changes in the real exchange rate may significantly influence the trade balance, but that the role of U.S. and Taiwan real incomes is less clearly established.

#### 4.3.4.2 The trade balance of Taiwan with Japan

The estimated long-run elasticity with respect to the real exchange rate is 0.614 (equation (45.1) in Table 18), implying that to eliminate Taiwan's trade deficit with Japan, a currency depreciation of 162.87 percent would be necessary. In equation (45.2), the

coefficient of the error correction term is -0.636, suggesting relatively fast adjustment to equilibrium or elimination of 60 percent of the disequilibrium in the first year. All of the estimated short-run elasticities were found to be lower than their long-run values.

In equation (45.4), the Saikkonen (1991) model, the estimated long-run elasticity with respect to the real exchange rate, Japanese real GNP, and Taiwan's real GNP are all insignificantly different from zero; when potential endogeneity bias is corrected for, there is no significant evidence that changes in the real exchange rate and Japanese and Taiwanese real incomes influence the trade balance.

All of the estimated long-run and short-run elasticities of the trade balance with respect to the real exchange rate are greater in the Taiwan-U.S. case than in the Taiwan-Japan case; Taiwan's trade balance with Japan appears to be less sensitive to exchange rate changes than is its trade balance with the United States. However, the broad J-curve effect appears in the Taiwan-U.S. case, while no J-curve effect emerges in the case of Taiwan-Japan trade.

One possible explanation for the different trade balance elasticities between Taiwan-U.S. and Taiwan-Japan trade with respect to the real exchange rate may be that the source of Taiwan's large trade surplus with the United States is mainly nondurable consumer goods. In contrast, the largest source of Taiwan's trade deficit with Japan comes from durable consumer and capital goods. Expenditures on durable consumer and capital goods are less sensitive to changes in the exchange rate as compared to nondurable consumer goods; this is so because the purchasers of durable goods need a longer time to react to price changes than these of nondurable goods.

The absolute value of the coefficient of the error correction term in equation (44.2) is slightly lower than that of equation (45.2) implying that the speed of adjustment in Taiwan's trade balance with the U.S. is relatively slower than that of Taiwan's trade balance with Japan.

#### 4.3.5 Evaluating the evidence on trade balance adjustment

The estimated results of the structural and reduced-form equations in sections 4.3.3 and 4.3.4 are generally supportive of the importance of the exchange rate in trade balance adjustment. The evidence of the trade balance adjustment is evaluated systematically in this section. This includes an analysis of the validity of the modified Bickerdike-Robinson-Metzler condition, an examination of evidence on structural rigidity in trade volumes and prices, and a comparison of the estimated results of the structural and reduced-form equations.

One way to view the implication of the estimated results of this study is to compute the modified Bickerdike-Robinson-Metzler condition derived in Chapter 3. The modified Bickerdike-Robinson-Metzler condition provides a critical elasticities condition for a positive effect of a devaluation on the trade balance when a country depends heavily on imports of various raw materials, energy, and other intermediate inputs for production. Recall that the original and modified Bickerdike-Robinson-Metzler conditions are as follows:

The original Bickerdike-Robinson-Metzler condition:

$$(8)'' \quad \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} > 1.$$

The modified Bickerdike-Robinson-Metzler condition:

$$(24) \quad \frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} - \frac{s_l \cdot s_m \cdot (d_x - 1)}{(s_x + d_x)(s_m + d_m)} > 1$$

where  $d_x$  = price elasticity of export demand

$s_x$  = export price elasticity of export supply

$d_m$  = price elasticity of import demand

$s_m$  = price elasticity of import supply.

$s_I$  = import price elasticity of export supply.

The term  $\frac{d_x \cdot (s_x + 1)}{(s_x + d_x)}$  represents the effect of changes in the exchange rate on the export market and  $\frac{d_m \cdot (s_m + 1)}{(s_m + d_m)}$  the effect of changes in the exchange rate on the import market. Therefore,  $\frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)}$  represents the trade balance improvement effect of changes in the exchange rate on the trade balance, while  $-\frac{s_I \cdot s_m \cdot (d_x - 1)}{(s_x + d_x)(s_m + d_m)}$

represents the supply shock effect of exchange rate changes on the export market.

As was mentioned in Chapter 3, it is more difficult to satisfy the modified Bickerdike-Robinson-Metzler condition than the original Bickerdike-Robinson-Metzler condition because the export demand elasticity is usually greater than one, so that the supply effect is often negative.

Using the estimated price elasticities of exports and imports presented in section 4.3.3, we can calculate the values of the trade balance improvement effect, the supply shock effect, and their total effect to check whether the original and modified Bickerdike-Robinson-Metzler conditions hold. Table 19 shows the results of these individual and summed values for the cointegrating regression, Saikkonen (1991), error correction, and first difference regression models. The first two models inspect the long-run equilibrium cases, while the last two models examine the short-run dynamic situation. In columns (2) and (3) in Table 19, all of the values of the trade balance improvement effect and total effect are greater than one, indicating that both the original and modified Bickerdike-Robinson-Metzler conditions are satisfied. These results suggest that Taiwan may be able to use currency appreciation as a tool to reduce its trade surplus with the United States and currency depreciation as a tool to reduce its trade deficit with Japan.

Although the results in Table 19 also show that the value of the supply shock effect in the Saikkonen (1991) model is greater than in the cointegrating regression, the value of the trade balance improvement effect is much higher than the supply shock effect. Therefore, in the long run, the supply shock effect in the export market appears not to be a dominant factor that determines the total effect of exchange rate changes on the trade balance; one possible explanation is that consumers are sensitive to changes in price and producers are thus not willing to increase the price to maximize their profits even when a supply shock has increased the cost of production.

Columns (4) and (5) in Table 19 show that in the short run, all the trade balance improvement effect are smaller than one and most total effect are less than zero, indicating that both the original and modified Bickerdike-Robinson-Metzler conditions appear not to be satisfied. That is, a depreciation of Taiwan's currency may not lead to an improvement in the bilateral trade balances in the first year.

By analyzing the components of the original and modified Bickerdike-Robinson-Metzler conditions, the results of Table 19 show that the value of the trade balance improvement effect is relatively smaller than that of the supply shock effect. Therefore, in the short run, the impact of a supply shock in the export market may be a dominant factor that determines the total effect of changes in the exchange rate on the trade balance; one potential interpretation is that consumers are insensitive to changes in price, producers can raise the price to maximize their profits when a supply shock increases the cost of production.

Table 19 shows that the supply side effect does not always have the expected negative sign. An explanation is that, as mentioned in the last paragraph, demand may be insensitive to price changes when supply effect shifts the production cost in the short run. If the demand elasticity of exports is less than one, export revenue will not fall with the increase in price.

Comparing the values in rows (c) and (g), which are the results of the structural form equations, with the values in rows (d) and (h), i.e., the results of the reduce-form equations, it should be noted that the estimated effects of changes in the exchange rate on the trade balance are similar in the cointegrating regression and Saikkonen (1991) models.

In this section, predicted values of the modified Bickerdike-Robinson-Metzler condition have been calculated from the estimated elasticities of this study; however, because the derivation of the confidence interval is unknown no confidence interval was reported on these modified Bickerdike-Robinson-Metzler condition calculations.<sup>32</sup> As variances are usually positively correlated with the number of variables in the calculation formula, the precision of the calculations may be quite low and it becomes impossible to construct a formal hypothesis test concerning the true value because of the unknown confidence interval.

While the modified Bickerdike-Robinson-Metzler condition analysis suggests that a devaluation can improve the trade balance, there is also evidence of short run J-curve effects. In both structural and reduced-form approaches, the short-run price elasticities were usually lower than the long-run price elasticities (Junz and Rhomberg, 1973; Goldstein and Khan, 1978; Artus and Knight, 1984), suggesting that the effects of exchange rate changes on trade flows increase over time. However, these low price elasticities in the short run may relate to the structural rigidity in trade volumes and may cause the J-curve effect. Magee (1973) distinguished between three periods in the J-curve effect. The first period is the “currency-contract period” during which the currency that is used in denominating the contracts does matter. The second is the “pass-through period”; in this period, the size of the price elasticities of exports and imports matter. As mentioned

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<sup>32</sup> A confidence interval describes a set of points that will contain the true value a certain percentage of the time (Leamer and Stern, 1970).

above, the price elasticities may be relatively low in short run as trade flows take time to respond to exchange rate changes.<sup>33</sup> The last is the “quantity-adjustment period.” In this period, consumers and producers have sufficient time to make their decision, and so, changes in trade quantities are sensitive to fluctuations in exchange rate.

The low price elasticities in the short run may not only relate to quantity rigidity but also to price rigidity. The “pass-through” and “hysteresis” approaches associated with pricing-to-market to explain the behavior of firms’ slow responses to exchange rate changes are relevant to this price rigidity. In particular, the hysteresis hypothesis claims that uncertainty about future movements in price leads to limited responsiveness of production to changes in prices (Dixit, 1989). Incomplete pass-through may diminish the effect of changes in the nominal exchange rate on the real exchange rate (Krugman and Obstfeld, 1994, p. 468). Hooper and Marquez (1993) provide a brief survey of recent literature on the price rigidity problem.

As estimated in sections 4.3.3 and 4.3.4, both the structural and reduced-form trade equations are generally supportive of the importance of the exchange rate in trade balance adjustment. In structural equations, the coefficients for responses of export demand to relative export price, export supply to import price, and import demand to relative import price have the expected negative signs, while the coefficients for responses of export supply to export price and the two income terms have the expected positive signs. In reduced-form equations, the coefficients for responses of trade balance to real exchange rate have the expected positive signs.

Both the structural and reduced-form models consistently find that the J-curve effect appears to exist in the case of Taiwan–U.S. bilateral trade. Taiwan’s exports to, imports

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<sup>33</sup> Junz and Rhomberg (1973) submitted five lag effects of price changes on trade quantities: recognition lags, decision lags, delivery lags, replacement lags, and production lags.

from, and trade balance with the United States do not respond until one year after the real exchange rate has changed. However, while the structural results suggest that the J-curve effect appears to exist in the case of Taiwan-Japan bilateral trade, the reduced-form model results suggest that the J-curve effect does not exist. In this case, the structural and reduced-form models suggest different conclusions.

Both the structural form and reduced-form equations suggest that the estimated price (exchange rate) elasticities of Taiwan–U.S. bilateral trade are higher than those of Taiwan-Japan trade. The results uniformly suggest that the trade flows between Taiwan and the United States are more sensitive to exchange rate changes than are the trade flows between Taiwan and Japan. As was mentioned earlier, one explanation for this is the different composition of trade between Taiwan and the United States and Taiwan and Japan. Both U.S. demand for Taiwan exports and Taiwan’s import demand from the United States are composed mostly of manufactured goods with high price elasticities. However, Japan’s demand for Taiwan exports are primarily agricultural products which have low elasticities, and Taiwan’s import demand from Japan is also generally made up of low elasticity semi-manufactures.

Both methods consistently find that the estimated price elasticity of the Saikkonen (1991) model is higher than its counterpart in the cointegrating regression. As was mentioned earlier, this is consistent with the existence of endogeneity bias in the cointegrating equation.

While both structural and reduced-form analyses provide support for the result that the exchange rate plays an important role in influencing trade flows, the estimated results are not uniformly strong. In structural equations, some short-run price elasticity estimates are insignificantly different from zero. The error correction and first-difference models tend to have relatively low  $\bar{R}^2$ , indicating they may not fit the data very well. In reduced-form equations, the coefficients for responses of the two income terms do not have the

expected signs, and many estimates are insignificantly different from zero.<sup>34</sup> Therefore, while the overall estimation results are supportive of my hypotheses, further study would be useful to collaborate these results.

#### 4.4 A Comparison of the Empirical Results of this Study and the Existing Trade Adjustment Literature

Since Rose and Yellen (1989) first examined the effects of nonstationary variables in their empirical study of trade balance adjustment, their model has been used repeatedly to derive estimates. A comparison of the empirical results derived in this dissertation with those in the existing trade adjustment literature that applied the Rose and Yellen (1989) model shows that the results of this study conform to many others. The dissertation finds that in the long run, a depreciation may improve the trade balance, paralleling the conclusions of Lasagabaster Latorre (1992) and Brada, Kutan and Zhou (1993). However, the results derived here differ from those of Rose and Yellen (1989), Rose (1990 and 1991), and Hsing (1993) for these studies found no evidence of exchange rates influencing the trade balance. However, as the data in Table 5 show this dissertation may be the only study that detects the existence of a J-curve effect by using the modern time-series method.

In specific comparisons of this study and the study by Rose and Yellen (1989), both used the modern time-series method to empirically explore the effect of changes in the exchange rate on the trade balance. However, while the results of this study indicate that the traditional trade adjustment mechanism indeed works after an initial period of perverse

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<sup>34</sup> One possible explanation as to why the reduced-form and structural form estimations sometimes find different results is the identification problem of the stationarity property. As mentioned in section 4.3.1, the stationarity property of the trade balance appears to be ambiguous. If the trade balance is stationary and the independent variables are nonstationary, then the estimates of the regression may be biased toward zero, and the equation will not detect anything about the trade relationship.

responses in trade flows to exchange rate changes, Rose and Yellen (1989) found no such relationship. The U.S. trade balance had huge deficits in 1976–1987 and began to improve in 1988. However, the research period for the study by Rose and Yellen (1989) is 1960–1985 and does not contain the years of U.S. trade improvement. Therefore, the conclusions of Rose and Yellen (1989) may not be completely accurate to the extent that it misleads policymakers about the role of exchange rate movements on trade balance adjustment. On the other hand, Taiwan had large trade surpluses in 1981–1989, but this surplus started to shrink in 1990. The data used in this dissertation spans 1965–1994; thus, it covers the period where Taiwan’s trade surplus began to fall. Consequently, the conclusions of this study would lead policymakers to consider more seriously a role for exchange rate changes in the process of trade adjustment.

Unlike most of existing studies, this paper uses the modern time-series method to estimate price and income elasticities.<sup>35</sup> However, as Table 12 shows, the estimated price and income elasticities derived in this dissertation do not dramatically differ from those of previous studies.

#### 4.5 Summary of the Estimated Results

The estimated results can be summarized as follows:

1. The estimated results of this study are generally supportive of the importance of the exchange rate in trade balance adjustment, suggesting that the exchange rate may be an effective tool to reduce Taiwan’s trade imbalance. This parallels the traditional findings of international trade economists. But the results in this study differ from those of Rose and Yellen (1989), Rose (1990 and 1991), and Hsing (1993) which found that changes in the exchange rates did not influence the trade balance.

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<sup>35</sup> Other papers that used the modern time-series method to estimate price and income elasticities of exports and imports include Moreno (1989) and Nedde (1992).

2. For Taiwan–U.S. and Taiwan-Japan bilateral trade, a J-curve effect is likely to exist with trade flows responding after one year has elapsed after the exchange rate changes.

3. The estimated price elasticities of Taiwan–U.S. bilateral trade are greater than that of Taiwan-Japan trade. This suggests that the trade flows between Taiwan and Japan may be less sensitive to exchange rate changes than are trade flows between Taiwan and the United States.

4. The absolute value of the coefficients of the error correction term are generally higher for Taiwan-Japan trade than that of Taiwan's trade with the United States. Therefore, the speed of adjustment in trade flows to the equilibrium values tends to be relatively slower for Taiwan–U.S. trade as compared to trade between Taiwan and Japan.

5. The estimated results of four specifications (the cointegrating regression, error correction, first difference regression, and the Saikkonen (1991) models) are not dramatically different. This implies that the results are generally robust and tend not to be sensitive to specification changes.

6. The estimated results suggest that the modified Bickerdike-Robinson-Metzler condition holds, implying that a depreciation of the New Taiwan dollar relative to a foreign currency may improve Taiwan's trade balance.

7. In the long run, the supply shock effect of a change in import price on exports appears not to dominate the effect of exchange rate changes on the trade balance. However, in the short run, the effect of a supply shock may dominate the effect of exchange rate changes on the trade balance, so that the short-run trade balance response may be negative.

8. The estimated income elasticities of exports are much higher than the estimated income elasticities of imports, supporting the validity of the unequal income elasticity hypothesis of Houthakker and Magee (1969).

## CHAPTER 5

### CONCLUSION

Trade imbalances have been a worldwide concern in recent years and has been an issue for Taiwan in particular. Throughout the 1980s, Taiwan consistently had the highest ratio of trade surplus relative to output than any other country. Although in the 1990s this has not always been true, Taiwan remains one of the major trade surplus countries in the world.

In terms of Taiwan's bilateral relationships, the United States and Japan are Taiwan's two largest trade partners. However, Taiwan's huge and persistent trade surplus with the United States and its trade deficit with Japan have been the main sources of trade conflicts between Taiwan and these two countries in the past decade.

In the late 1980s, the United States repeatedly accused Taiwan of manipulating its exchange rate to gain a competitive edge and boost its trade surpluses. Responding to the U.S. pressure and emerging protectionist sentiment, Taiwan allowed its currency to drastically appreciate against the U.S. dollar. However, even after the exchange rate changed Taiwan's trade surplus continued to increase for one year before finally dropping. From this experience, there emerged an interesting question; that is does the exchange rate play a crucial role in Taiwan's trade balance adjustment process?

This dissertation looks into this question and investigates the effect of exchange rate changes on Taiwan's trade balance. The basic theory and a background overview of the econometrics literature on trade adjustment is presented. Studies that explored the sensitivity of trade flows to movements in exchange rates were used as a basis for modeling Taiwan's trade equations.

After fifty years of study, estimates of trade elasticities for both price elasticities of exports and imports range widely. However, in general, the results indicate that the sum of

the price elasticities of exports and imports is typically much greater than one (in absolute value terms), implying that a country can improve its trade balance by devaluing its currency.

However, the empirical results of Rose and Yellen (1989) and Rose (1990 and 1991) dispute this conventional view. Applying the modern time-series method, these authors found no evidence that exchange rates influence trade balances, whether it be a developed or developing country. Their findings motivated this study to use the method of modern time-series econometrics as well to estimate and evaluate the sensitivity of exchange rate changes on Taiwan's trade flows.

In this dissertation, a partial equilibrium empirical trade adjustment model that explicitly regarded the supply effect of changes in import prices on the export market was presented. This was done to reflect the fact that Taiwan has few natural resources and relies to a large extent on imported raw materials, energy, and other intermediate inputs for its production.

Since Rose and Yellen (1989) first used a partial reduced form specification of the trade balance equation and applied the modern time-series method, Rose (1990 and 1991), Lasagabaster Latorre (1992), Brada, Kutan and Zhou (1993), and Hsing (1993) have also employed the same econometric method to examine the relationship between exchange rates and trade balances. However, as mentioned in Chapter 4, econometricians who are estimating price and income elasticities of exports and imports have been hesitant to use the modern time-series method. Modern time-series studies of the structural forms of export supply and demand functions have also been few. In adding economic knowledge to the existing literature, the challenge of this dissertation is to run both the structural form and reduced form specifications by applying the methods of modern time-series econometrics to analyze the long-run trade adjustment process and its relation to short-run dynamics. The

structural form equation can reveal insight into the supply side effect, but the reduced form equation cannot.

Several findings of this study will be useful for future specification and application of models of trade adjustment. The estimates generally support a role for exchange rate policy as a tool to reduce Taiwan's trade imbalance. That is, Taiwan's exports and imports appear to be sensitive to changes in exchange rates. The evidence is that in the long run, the sum of the price elasticities of exports and imports is greater than one. In addition, depreciation of the NT\$ is found to have a positive effect on the trade balance. These findings are consistent with the traditional findings of international trade economists which have been challenged by recent studies.

However, in the short run, the J-curve effect may exist. The sum of the price elasticities of exports and imports is found to be less than one, suggesting that Taiwan's exports and imports are insensitive to changes in exchange rates in the short run. As a result, a depreciation in Taiwan's currency is likely to have an initial perverse effect on the trade balance.

The responsiveness of Taiwan-Japan trade to exchange rate changes appears to be lower than that of Taiwan-U.S. trade. One possible explanation for this is the distinctly different composition of goods in Taiwan-U.S. and Taiwan-Japan trade.

Although in the long run bilateral trade between Taiwan and Japan is found to be less sensitive to exchange rate changes than that between Taiwan and the United States, Taiwan-Japan trade appears to respond more quickly to restore the trade flows back to their long-run equilibrium than does Taiwan-U.S. trade. Empirical evidence of this is that the coefficients of the error correction terms of Taiwan-Japan trade are generally higher than that of Taiwan-U.S. trade. Thus when trade flows deviate from their long-run equilibriums, Taiwan-Japan trade may have a stronger feedback effect than does Taiwan-U.S. trade.

In the long run, the supply effect of a change in import price on Taiwan's exports might not be able to dominate over the effects of exchange rate changes on the trade balance. But it may do so in the short run. Nevertheless, the supply effect consideration generally does not differ from the results of the traditional literature.

One noteworthy point is that the sample period selected may be responsible for the different conclusions reached in this dissertation and the study by Rose and Yellen (1989). Rose and Yellen (1989) used data over the 1960–1985 period and found that a currency depreciation did not necessarily improve the trade balance. However, when one considers that the U.S. trade deficit peaked in 1987 and began declining in 1988, it is clear that the study by Rose and Yellen (1989) did not contain the interval of U.S. trade deficit reduction and therefore, the conclusions reached may be misleading policymakers as to the importance of changes in exchange rates on the process of trade balance adjustment. In contrast, the sample period of this study is 1965–1994 and covers both the upsurge and diminishing periods of Taiwan's trade surplus. Therefore, the estimates derived in this study, which suggest that policymakers take into account the effects of exchange rate changes on trade flows, would appear to be more accurate in terms of reflecting a longer time frame.

However, this study does have certain limitations. The first limitation is that the sample size is too small to avoid a considerable small sample bias. The 1965–1994 data set that is available includes only annual data, while quarterly data of Taiwan are only available after 1976 (for example, Taiwan's unit values of exports and imports) or 1979 (for example, Taiwan's GNP). However, Shiller and Perron (1985) concluded that the power of the unit root test depends on the span of the data rather than the number of observations. Since the annual data available span a longer time period than the quarterly data, annual data are used in this study. However, the disadvantage of annual data is that the small number of observations may cause the problem of finite-sample bias.

In addition, while my empirical evidence is supportive of the importance of the exchange rate in trade balance adjustment, the econometric results are not uniformly strong. Not all coefficients have the expected sign, some coefficient estimates are not statistically significant, and some equations with low  $R^2$  may not adequately explain the variation in the dependent variables. In addition, unit root tests do not always unambiguously establish stationarity properties of variables, and the results of cointegration tests are sometimes inconclusive. Further research would be desirable to clarify these issues.

A further limitation is that this study has neglected the booming bilateral trade between Taiwan and China in recent years. Since 1990, China has exceeded Japan to become the second-largest export market for Taiwan goods. However, the availability and accuracy of trade data is a problem because some Taiwan-China trade is, in fact, indirect trade through Hong Kong.

I do not claim that this dissertation has fully explained the problem of Taiwan's trade adjustment. However, these findings may serve to remind policymakers in Taiwan to remember the lessons of Taiwan's involuntary and painful trade adjustment process of the past decade. This study suggests that the exchange rate policy appears to be an effective tool and it may also be a necessary part of successful adjustment for reducing trade imbalances. The elasticity estimates of this study provide information about the magnitudes of trade adjustment that would occur from a devaluation policy. However, the experience of slow Taiwan-U.S. trade adjustment also indicates that an expansionary fiscal policy in Taiwan may also be necessary to smooth the trade adjustment process.

This study has focused on the experience of Taiwan, applying the elasticities approach and the econometric methodology of modern time-series. To extend this research, other country cases could be studied, alternative theoretical approaches might be applied, and alternative econometric methodologies may be employed in future research.

## APPENDIX A: TABLES

Table 1

The composition of Taiwan's bilateral trade with the U.S. and Japan, 1993

(US\$ billions, percentage)

Item	Exports to		Imports from	
	United States	Japan	United States	Japan
(1)	(2)	(3)	(4)	(5)
Agricultural products	0.7 (3.0%)	2.6 (28.9%)	0.9 (5.4%)	0.0 (0%)
Textile products	2.7 (11.5%)	0.5 (5.6%)	0.0 (0%)	0.7 (3.0%)
Rubber and plastic products	1.2 (5.1%)	0.5 (5.6%)	0.0 (0%)	0.0 (0%)
Basic metals and articles thereof	2.3 (9.8%)	1.0 (11.1%)	0.7 (4.2%)	2.9 (12.5%)
Chemicals	0.0 (0%)	0.0 (0%)	2.2 (13.2%)	2.2 (9.5%)
Machinery and electrical equipment	10.3 (43.8%)	1.9 (21.1%)	4.4 (26.3%)	10.9 (47.0%)
Transportation equipment	1.2 (5.1%)	0.0 (0%)	2.4 (14.4%)	2.2 (9.5%)
Others	5.1 (21.7%)	2.5 (27.8%)	6.1 (36.5%)	4.3 (18.5%)
<b>Total</b>	<b>23.5</b>	<b>9.0</b>	<b>16.7</b>	<b>23.2</b>

Sources: Taiwan statistical data book 1994.

Table 2

The correlation between the nominal and real exchange rate, annual data 1965–1994<sup>a</sup>

	Taiwan–U.S.	Taiwan–Japan
Levels of nominal and real exchange rates	0.71	0.96
Change rates in nominal and real exchange rates	0.67	0.94

Sources: International Monetary Fund, International Financial Statistics (various years) and Financial Statistics, Taiwan District, Republic of China (various years).

Note: a. The real exchange rate of the New Taiwan dollar against the U.S. dollar is defined as the nominal exchange rate (i.e., the number of units of New Taiwan dollar per U.S. dollar) multiplied by the ratio of the U.S. producers price index to the Taiwanese wholesale price index. The real exchange rate of the New Taiwan dollar against the Japanese yen is defined as the nominal exchange rate (i.e., the number of units of New Taiwan dollar per Japanese yen) multiplied by the ratio of the Japanese wholesale price index to the Taiwanese wholesale price index.

Table 3

The correlation between the nominal and real trade balance, annual data 1965–1994<sup>a</sup>

	Taiwan–U.S.	Taiwan–Japan
Levels of nominal and real trade balances	0.69	-0.09
Changes in nominal and real trade balances	0.70	0.43

Sources: Taiwan statistical data book (various years).

Note: a. The nominal trade balance is defined as exports minus imports. The real trade balance is defined as the ratio of exports to imports.

Table 4

The price elasticity conditions of trade balance improvement of the Bickerdike-Robinson-Metzler model

Cases	Price elasticity assumptions	Price elasticity conditions
Large country	$s_x, s_m, d_x,$ and $d_m$ are finite	The Bickerdike-Robinson-Metzler condition: $\frac{d_x \cdot (s_x + 1)}{(s_x + d_x)} + \frac{d_m \cdot (s_m + 1)}{(s_m + d_m)} > 1$
Small country	$s_m = d_x = \infty$	Trade balance unambiguously improves ( $\because s_x + d_m > 0$ )
Infinite supply elasticities	$s_m = s_x = \infty$	The Marshall-Lerner condition: $d_x + d_m > 1$

Note:  $d_x$  is the price elasticity of export demand,  $d_m$  is the price elasticity of import demand,  $s_x$  is the price elasticity of export supply, and  $s_m$  is the price elasticity of import supply.

Table 5  
Integrated order, cointegration relationship, and J-curve effects found in selected papers

Study	Data; frequency; sample period	Country	Integrated order			Cointegration	Exchange rates influence trade balances	J-curve effect
			B	y, y*	q			
Rose and Yellen (1989)	Bilateral Quarterly; 1960:I-1985:IV	United States	I(1)	I(1)	I(1)	No	No	No
Rose (1990)	Multilateral Annual; 1970-1988 Quarterly; 1977:I-1987:IV	Thirty developing countries	I(1)	I(1)	I(1)	No	No	No
Bahmani-Oskooee (1991)	Multilateral Quarterly; 1973:I-1988:IV	Eight developing countries	I(1)	N/A	I(1)	B and q	Yes	N/A
Rose (1991)	Bilateral Monthly; 1974:I-1986:12	United States	I(1)	I(1)	I(1)	No	No	No
Lasagabaster Latorre (1992)	Bilateral Monthly; 1974:I-1987:12	France, Germany, Italy, Netherlands, Spain, United Kingdom	I(1)	I(1)	I(1)	B, y, y*, q	Yes	No
Mahdavi and Sohrabian (1993)	Multilateral Quarterly; 1973:II-1989:III	United States	I(1)	N/A	I(1)	No	No	No
Brada, Kutan, and Zhou (1993)	Multilateral Quarterly; 1980:I-1989:IV	China	I(1)	I(1)	I(1)	B, y, y*, q	Yes	No

(continued)

Table 5 (continued)  
 Integrated order, cointegration relationship, and J-curve effects found in selected papers

Study	Data; frequency; sample period	Country	Integrated order			Cointegration	Exchange rates influence trade balances	J-curve effect
			B	y, y*	q			
Hsing (1993)	Bilateral Quarterly; 1973:I-1991:IV	Korea, Taiwan	I(1)	I(1)	I(1)	No	No	No
Arize (1994)	Multilateral Quarterly; 1973:I-1991:I	Nine Asian countries	I(1)	N/A	I(1)	B and q	Yes	N/A

Note: B refers to the real trade balance; y, real domestic income; y\*, real foreign income; q, real exchange rate; I(1), integrated of order one. N/A = not available.

Table 6

The price elasticity condition of trade balance improvement of the modified Bickerdike-Robinson-Metzler model

Cases	Price elasticity assumptions	Price elasticity conditions
Large country	$s_x, s_m, s_l, d_x,$ and $d_m$ are finite	The modified Bickerdike-Robinson-Metzler condition: $\frac{d_x(s_x + 1)}{(s_x + d_x)} + \frac{d_m(s_m + 1)}{(s_m + d_m)} - \frac{s_l \cdot s_m(d_x - 1)}{(s_m + d_m)(s_x + d_x)} > 1$
Small country	$s_m = d_x = \infty$	$s_x + d_m > s_l$
Infinite supply elasticities	$s_m = s_x = \infty$	The Marshall-Lerner condition: $d_x + d_m > 1$

Note:  $d_x$  is the price elasticity of export demand,  $d_m$  is the price elasticity of import demand,  $s_x$  is the price elasticity of export supply,  $s_m$  is the price elasticity of import supply, and  $s_l$  is the import price elasticity of export supply.

Table 7  
Augmented Dickey-Fuller unit root tests

(1) Variable	(2) k	$y_t = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$		$y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$		$y_t = \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$	
		(3) $H_0: (\alpha_0, \alpha_2, \gamma)$ $= (\alpha_0, \alpha_2, 1)$	(4) given $\gamma = 1$ , $H_0: (\alpha_0, \alpha_2) = (\alpha_0, 0)$	(5) $H_0: (\alpha_0, \gamma)$ $= (\alpha_0, 1)$	(6) given $\gamma = 1$ , $H_0: \alpha_0 = 0$	(7) $H_0: \gamma = 1$ level	(8) $H_0: \gamma = 1$ first-difference
Japan real GNP	3	-3.44 <sup>a</sup>	2.66 <sup>b</sup>	-1.26 <sup>c</sup>	1.31 <sup>d</sup>	2.07 <sup>e</sup>	-1.74
U.S. real GNP	0	-3.25	2.55	-0.93	1.10	6.61	-2.49
Taiwan real GNP	0	-1.27	1.15	-1.98	2.74	13.72	-1.19
Unit value of exports	0			-1.70	1.90	2.51	-2.92
Unit value of imports	0			-1.74	1.92	1.63	-2.76
Relative import price	0			-1.16	0.96	-1.13	-3.60
<u>Taiwan-U.S. bilateral trade:</u>							
Trade balance	0	-1.95	-0.59	-2.82	2.67	-1.11	-4.14
Export quantity	3	-1.19	0.14	-2.66	2.75	1.12	-2.22
Import quantity	0	-2.55	2.50	-0.73	1.02	4.23	-3.94
Relative export price	0			-2.15	0.34	-0.31	-4.59
Real exchange rate	0			-2.38	2.09	-0.31	-4.99

(continued)

Table 7 (continued)  
Augmented Dickey-Fuller unit root tests

(1) Variable	(2) k	$y_t = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$		$y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$		$y_t = \gamma y_{t-1} + \sum_{i=2}^k \beta_i \Delta y_{t-i+1} + u_t$	
		(3) $H_0: (\alpha_0, \alpha_2, \gamma) = (\alpha_0, \alpha_2, 1)$	(4) given $\gamma = 1$ , $H_0: (\alpha_0, \alpha_2) = (\alpha_0, 0)$	(5) $H_0: (\alpha_0, \gamma) = (\alpha_0, 1)$	(6) given $\gamma = 1$ , $H_0: \alpha_0 = 0$	(7) $H_0: \gamma = 1$ level	(8) $H_0: \gamma = 1$ first-difference
<u>Taiwan-Japan bilateral trade:</u>							
Tradebalance	0	-3.45	1.93	-2.78	-2.81	-0.23	-6.16
Export quantity	0	-2.10	1.97	-0.80	1.24	2.82	-4.00
Import quantity	0	-2.22	2.02	-1.07	1.50	4.18	-3.63
Relative export price	4			-0.21	0.04	-1.37	-7.50
Real exchange rate	3			-2.21	-2.22	0.21	-6.77

Notes: All variables are expressed in logarithms and k is the number of lag terms.

- The critical value at the 5% significance level is -3.57 (MacKinnon, 1991).
- The critical value at the 5% significance level is 2.85 (Dickey and Fuller, 1981).
- The critical value at the 5% significance level is -2.97 (MacKinnon, 1991).
- The critical value at the 5% significance level is 2.61 (Dickey and Fuller, 1981).
- The critical value at the 5% significance level is -1.95 (MacKinnon, 1991).

Table 8

## The results of the unit root tests

(1)	(2)
Variable	Order of integration
Japan real GNP	I(1)
U.S. real GNP	I(1)
Taiwan real GNP	I(1)
Unit value of exports	I(1)
Unit value of imports	I(1)
Relative import price	I(1)
<u>Taiwan-U.S. bilateral trade:</u>	
Tradebalance	I(1)
Export quantity	I(1)
Import quantity	I(1)
Relative export price	I(1)
Real exchange rate	I(1)
<u>Taiwan-Japan bilateral trade:</u>	
Tradebalance	I(1)
Export quantity	I(1)
Import quantity	I(1)
Relative export price	I(1)
Real exchange rate	I(1)

Note: I(1) indicates that the variable is integrated of order one.

Table 9  
Cointegration tests

Equation	Number of regressors (excluding constant)	Augmented Dickey and Fuller test		Park (1990) statistic <sup>b</sup>	Harris and Inder (1994) statistic <sup>c</sup>
		Coefficient	Dickey and Fuller statistic <sup>a</sup>		
U.S. demand for Taiwan exports	3	0.607	-2.747	0.056	0.1425
Taiwan export supply to the U.S.	3	0.617	-2.571	0.321	0.1419
Taiwan import demand from the U.S.	2	0.263	-4.039	1.646	0.1797
Trade balance of Taiwan with the U.S.	4	0.574	-2.607	0.011	0.1062
Japan demand for Taiwan exports	2	0.436	-3.963	1.781	0.1034
Taiwan export supply to Japan	2	0.361	-3.646	0.059	0.1028
Taiwan import demand from Japan	2	0.698	-2.477	3.315	0.1959
Trade balance of Taiwan with Japan	3	0.338	-3.600	5.519	0.1530

Notes:

- a. The critical values at the 5% significance level of two, three, and four regressors are -4.036, -4.482, and -4.897 (MacKinnon, 1991).
- b. The critical value of  $\chi^2(1)$  at the 5% significance level is 3.84.
- c. The critical values at the 5% significance level of two, three, and four regressors are 0.2177, 0.1590, and 0.1204 (Harris and Inder, 1994).

Table 10

Estimation of U.S. demand for Taiwan exports, annual data 1965–1994

Equation (38.1): cointegrating regression model

$$\text{LEX}_t = -17.395 - 0.981 \text{LPX}_t + 2.894 \text{LUSGNP}_t + 0.0542 \text{AIP}_t$$

$$\bar{R}^2 = 0.980 \quad \text{DW} = 0.638 \quad \text{Q}(7) = 21.94 \quad s = 0.183$$

Equation (38.2): error correction model

$$\Delta \text{LEX}_t = -0.104 \text{ECM}_{t-1} - 0.207 \Delta \text{LPX}_t - 0.660 \Delta \text{LPX}_{t-1} + 2.387 \Delta \text{LUSGNP}_t + 0.0521 \Delta \text{AIP}_t$$

(-0.65)                      (-0.74)                      (-2.16)                      (3.24)                      (5.26)

$$\bar{R}^2 = 0.715 \quad \text{DW} = 1.363 \quad \text{Q}(7) = 7.646 \quad s = 0.091$$

Equation (38.3): difference regression model

$$\Delta \text{LEX}_t = -0.224 \Delta \text{LPX}_t - 0.752 \Delta \text{LPX}_{t-1} + 2.165 \Delta \text{LUSGNP}_t + 0.0556 \Delta \text{AIP}_t$$

(-0.82)                      (-2.82)                      (3.36)                      (6.83)

$$\bar{R}^2 = 0.722 \quad \text{DW} = 1.473 \quad \text{Q}(7) = 6.36 \quad s = 0.090$$

Equation (38.4): Saikkonen (1991) model

$$\text{LEX}_t = -18.41 - 1.747 \text{LPX}_t + 2.571 \text{LUSGNP}_t + 0.065 \text{AIP}_t$$

(-7.34)                      (-4.11)                      (8.63)                      (5.01)

$$- 0.264 \Delta \text{LPX}_{t+1} + 1.411 \Delta \text{LPX}_t + 0.697 \Delta \text{LPX}_{t-1}$$

(-0.65)                      (3.26)                      (1.76)

$$+ 1.789 \Delta \text{LUSGNP}_{t+1} + 0.811 \Delta \text{LUSGNP}_t + 0.726 \Delta \text{LUSGNP}_{t-1}$$

(1.34)                      (0.59)                      (0.51)

$$+ 0.019 \Delta \text{AIP}_{t+1} - 0.008 \Delta \text{AIP}_t - 0.031 \Delta \text{AIP}_{t-1}$$

(0.64)                      (-0.34)                      (-1.45)

$$\bar{R}^2 = 0.991 \quad \text{DW} = 0.820 \quad \text{Q}(6) = 12.33 \quad s = 0.103$$

Note: All variables are expressed in logarithms. LEX = export quantity; LPX = relative export price; LUSGNP = U.S. real GDP; AIP = degree of industrialization of Taiwan (determined as the ratio of Taiwan industrial production exports to total exports); and ECM = error correction term. *t* statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and *s* = standard error of the estimate.

Table 11

Estimation of Taiwan's export supply to the U.S., annual data 1965–1994

Equation (39.1): cointegrating regression model

$$\text{LEX}_t = 1.915 + 4.269 \text{LUVEX}_t - 2.378 \text{LUVIM}_t + 0.0516 \text{AIP}_t$$

$$\bar{R}^2 = 0.982 \quad \text{DW} = 0.753 \quad \text{Q}(7) = 17.74 \quad s = 0.173$$

Equation (39.2): error correction model

$$\Delta \text{LEX}_t = -0.336 \text{ECM}_{t-1} + 2.952 \Delta \text{LUVEX}_t - 2.078 \Delta \text{LUVIM}_t + 0.0538 \Delta \text{AIP}_t$$

$$\begin{array}{cccc} (-2.36) & (3.16) & (-3.23) & (7.26) \end{array}$$

$$\bar{R}^2 = 0.715 \quad \text{DW} = 1.363 \quad \text{Q}(7) = 7.646 \quad s = 0.116$$

Equation (39.3): difference regression model

$$\Delta \text{LEX}_t = 2.177 \Delta \text{LUVEX}_t - 1.542 \Delta \text{LUVIM}_t + 0.0546 \Delta \text{AIP}_t$$

$$\begin{array}{ccc} (2.30) & (-2.36) & (6.80) \end{array}$$

$$\bar{R}^2 = 0.436 \quad \text{DW} = 1.235 \quad \text{Q}(7) = 3.45 \quad s = 0.126$$

Equation (39.4): Saikkonen (1991) model

$$\text{LEX}_t = 4.973 + 3.115 \text{LUVEX}_t - 1.548 \text{LUVIM}_t + 0.035 \text{AIP}_t$$

$$\begin{array}{cccc} (5.33) & (5.43) & (-4.66) & (2.25) \end{array}$$

$$+ 3.798 \Delta \text{LUVEX}_{t+1} - 2.310 \Delta \text{LUVEX}_t - 0.502 \Delta \text{LUVEX}_{t-1}$$

$$\begin{array}{ccc} (2.90) & (-1.49) & (-0.43) \end{array}$$

$$- 2.371 \Delta \text{LUVIM}_{t+1} + 1.340 \Delta \text{LUVIM}_t - 1.450 \Delta \text{LUVIM}_{t-1}$$

$$\begin{array}{ccc} (-2.61) & (1.41) & (-2.00) \end{array}$$

$$- 0.035 \Delta \text{AIP}_{t+1} - 0.051 \Delta \text{AIP}_t - 0.027 \Delta \text{AIP}_{t-1}$$

$$\begin{array}{ccc} (-0.91) & (-2.22) & (-1.42) \end{array}$$

$$\bar{R}^2 = 0.991 \quad \text{DW} = 1.136 \quad \text{Q}(6) = 15.17 \quad s = 0.100$$

Note: All variables are expressed in logarithms. LEX = export quantity; LUVEX = unit value of exports; LUVIM = unit value of imports; AIP = degree of industrialization of Taiwan (determined as the ratio of Taiwan industrial production exports to total exports); and ECM = error correction term.  $t$  statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and  $s$  = standard error of the estimate.

Table 12

Estimation of Taiwan's import demand from the U.S., annual data, 1965-1994

Equation (40.1): cointegrating regression model

$$\text{LIM}_t = -0.829 - 1.049 \text{LPM}_t + 1.288 \text{LTWGNP}_t$$

$$\bar{R}^2 = 0.980 \quad \text{DW} = 0.981 \quad \text{Q}(7) = 16.01 \quad s = 0.124$$

Equation (40.2): error correction model

$$\Delta \text{LIM}_t = -0.422 \text{ECM}_{t-1} + 0.087 \Delta \text{LPM}_t - 0.862 \Delta \text{LPM}_{t-1} + 1.367 \Delta \text{LTWGNP}_t$$

(-2.73)                      (0.27)                      (-2.68)                      (6.18)

$$\bar{R}^2 = 0.715 \quad \text{DW} = 1.363 \quad \text{Q}(7) = 7.646 \quad s = 0.102$$

Equation (40.3): difference regression model

$$\Delta \text{LIM}_t = -0.197 \Delta \text{LPM}_t - 1.126 \Delta \text{LPM}_{t-1} + 1.422 \Delta \text{LTWGNP}_t$$

(-0.57)                      (-3.28)                      (5.76)

$$\bar{R}^2 = 0.250 \quad \text{DW} = 2.558 \quad \text{Q}(7) = 11.69 \quad s = 0.114$$

Equation (40.4): Saikkonen (1991) model

$$\text{LIM}_t = 3.661 - 2.166 \text{LPM}_t + 1.246 \text{LTWGNP}_t$$

(2.09)                      (-4.48)                      (34.94)

$$- 0.290 \Delta \text{LPM}_{t+1} + 1.703 \Delta \text{LPM}_t + 0.493 \Delta \text{LPM}_{t-1}$$

(-0.75)                      (3.47)                      (1.17)

$$- 0.174 \Delta \text{LTWGNP}_{t+1} - 0.190 \Delta \text{LTWGNP}_t + 0.440 \Delta \text{LTWGNP}_{t-1}$$

(-0.21)                      (-0.21)                      (0.50)

$$\bar{R}^2 = 0.988 \quad \text{DW} = 1.354 \quad \text{Q}(6) = 9.125 \quad s = 0.096$$

Note: All variables are expressed in logarithms. LIM = import quantity; LPM = relative import price; LTWGNP = Taiwan real GNP; and ECM = error correction term. *t* statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and *s* = standard error of the estimate.

Table 13  
The estimated price and income elasticities of Taiwan

Study	Data; Frequency; Sample period	Price elasticity		Income elasticity	
		Exports	Imports	Exports	Imports
Sheu (1973)	Multilateral; Annual; 1953-1971	- 0.37	- 0.03	2.67	1.51
Cline (1989)	Bilateral; Quarterly; 1973:I-1987:IV	- 3.00 (Taiwan-U.S.)	- 0.62 (Taiwan-U.S.)	3.00 (Taiwan-U.S.)	1.32 (Taiwan-U.S.)
		- 1.54 (Taiwan-Japan)	- 0.30 (Taiwan-Japan)	2.15 (Taiwan-Japan)	1.02 (Taiwan-Japan)
Cline (1989)	Multilateral; Quarterly; 1973:I-1987:IV	- 1.88	- 0.42	2.70	1.31
Moreno (1989)	Multilateral; Quarterly; 1974:I-1987:IV	- 0.79	- 1.44	2.87	0.82
This estimate	Bilateral; Annual; 1965-1994	- 1.75 (Taiwan-U.S.)	- 2.17 (Taiwan-U.S.)	2.57 (Taiwan-U.S.)	1.25 (Taiwan-U.S.)
		- 1.63 (Taiwan-Japan)	- 1.15 (Taiwan-Japan)	1.90 (Taiwan-Japan)	1.25 (Taiwan-Japan)

Sources: Sheu (1975, Table 1, p. 254); Cline (1989, Table 4.3, p. 155; Table 4A.2, p. 172; and Table 4A.3, p. 174); and Moreno (1989, Table 2, p. 39).

Table 14

Estimation of Japan's demand for Taiwan's exports, annual data 1965–1994

Equation (41.1): cointegrating regression model

$$\text{LEX}_t = -19.439 - 0.641 \text{LPX}_t + 2.187 \text{LJGNP}_t$$

$$\bar{R}^2 = 0.957 \quad \text{DW} = 0.879 \quad \text{Q}(7) = 16.35 \quad s = 0.213$$

Equation (41.2): error correction model

$$\Delta \text{LEX}_t = -0.507 \text{ECM}_{t-1} + 0.048 \Delta \text{LPX}_t - 0.217 \Delta \text{LPX}_{t-1} + 1.758 \Delta \text{LJGNP}_t$$

$$(-3.13) \quad (0.19) \quad (-0.78) \quad (3.72)$$

$$\bar{R}^2 = 0.397 \quad \text{DW} = 1.535 \quad \text{Q}(7) = 7.582 \quad s = 0.139$$

Equation (41.3): difference regression model

$$\Delta \text{LEX}_t = 0.044 \Delta \text{LPX}_t - 0.536 \Delta \text{LPX}_{t-1} + 2.046 \Delta \text{LJGNP}_t$$

$$(0.15) \quad (-1.77) \quad (3.80)$$

$$\bar{R}^2 = 0.184 \quad \text{DW} = 1.843 \quad \text{Q}(7) = 7.47 \quad s = 0.161$$

Equation (41.4): Saikkonen (1991) model

$$\text{LEX}_t = -13.93 - 1.625 \text{LPX}_t + 1.900 \text{LJGNP}_t$$

$$(-2.34) \quad (-2.12) \quad (5.18)$$

$$- 0.089 \Delta \text{LPX}_{t+1} + 1.345 \Delta \text{LPX}_t + 0.431 \Delta \text{LPX}_{t-1}$$

$$(-0.25) \quad (2.55) \quad (1.14)$$

$$- 2.561 \Delta \text{LJGNP}_{t+1} + 0.745 \Delta \text{LJGNP}_t - 1.328 \Delta \text{LJGNP}_{t-1}$$

$$(-1.55) \quad (0.48) \quad (-0.94)$$

$$\bar{R}^2 = 0.976 \quad \text{DW} = 1.050 \quad \text{Q}(6) = 18.60 \quad s = 0.149$$

Note: All variables are expressed in logarithms. LEX = export quantity; LPX = relative export price; LJGNP = Japan real GNP; and ECM = error correction term. t statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung Box Q statistic; and s = standard error of the estimate.

Table 15

Estimation of Taiwan's export supply to Japan, annual data 1965–1994

Equation (42.1): cointegrating regression model

$$\text{LEX}_t = -6.157 + 7.019 \text{LUVEX}_t - 4.056 \text{LUVIM}_t$$

$$\bar{R}^2 = 0.974 \quad \text{DW} = 1.269 \quad \text{Q}(7) = 9.26 \quad s = 0.165$$

Equation (42.2): error correction model

$$\Delta \text{LEX}_t = -0.597 \text{ECM}_{t-1} + 5.362 \Delta \text{LUVEX}_t - 2.939 \Delta \text{LUVIM}_t$$

$$\begin{matrix} (-2.93) & (4.74) & (-3.82) \end{matrix}$$

$$\bar{R}^2 = 0.296 \quad \text{DW} = 1.753 \quad \text{Q}(7) = 4.19 \quad s = 0.149$$

Equation (42.3): difference regression model

$$\Delta \text{LEX}_t = 4.629 \Delta \text{LUVEX}_t - 2.863 \Delta \text{LUVIM}_t$$

$$\begin{matrix} (3.71) & (-3.29) \end{matrix}$$

$$\bar{R}^2 = 0.099 \quad \text{DW} = 1.933 \quad \text{Q}(7) = 5.03 \quad s = 0.169$$

Equation (42.4): Saikkonen (1991) model

$$\text{LEX}_t = -6.976 + 7.453 \text{LUVEX}_t - 4.307 \text{LUVIM}_t$$

$$\begin{matrix} (-14.45) & (16.92) & (-11.99) \end{matrix}$$

$$+ 3.064 \Delta \text{LUVEX}_{t+1} - 2.151 \Delta \text{LUVEX}_t - 1.405 \Delta \text{LUVEX}_{t-1}$$

$$\begin{matrix} (1.78) & (-1.27) & (-1.04) \end{matrix}$$

$$- 1.105 \Delta \text{LUVIM}_{t+1} + 1.851 \Delta \text{LUVIM}_t + 0.532 \Delta \text{LUVIM}_{t-1}$$

$$\begin{matrix} (-0.91) & (1.58) & (0.60) \end{matrix}$$

$$\bar{R}^2 = 0.979 \quad \text{DW} = 0.896 \quad \text{Q}(6) = 21.60 \quad s = 0.138$$

Note: All variables are expressed in logarithms. LEX = export quantity; LPX = relative export price; LUVEX = unit value of exports; LUVIM = unit value of imports; and ECM = error correction term. t statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and s = standard error of the estimate.

Table 16

Estimation of Taiwan's import demand from Japan, annual data 1965–1994

Equation (43.1): cointegrating regression model

$$\text{LIM}_t = -10.384 - 0.859 \text{LPM}_t + 1.239 \text{LTWGNP}_t$$

$$\bar{R}^2 = 0.970 \quad \text{DW} = 0.507 \quad \text{Q}(7) = 34.07 \quad s = 0.161$$

Equation (43.2): error correction model

$$\Delta \text{LIM}_t = -0.476 \text{ECM}_{t-1} + 0.215 \Delta \text{LPM}_t - 0.410 \Delta \text{LPM}_{t-1} + 1.527 \Delta \text{LTWGNP}_t$$

$$\begin{matrix} (-2.60) & (0.37) & (-0.80) & (7.41) \end{matrix}$$

$$\bar{R}^2 = 0.517 \quad \text{DW} = 2.250 \quad \text{Q}(7) = 8.13 \quad s = 0.097$$

Equation (43.3): difference regression model

$$\Delta \text{LIM}_t = -0.702 \Delta \text{LPM}_t - 1.020 \Delta \text{LPM}_{t-1} + 1.515 \Delta \text{LTWGNP}_t$$

$$\begin{matrix} (-1.38) & (-2.02) & (6.63) \end{matrix}$$

$$\bar{R}^2 = 0.406 \quad \text{DW} = 2.693 \quad \text{Q}(7) = 24.06 \quad s = 0.107$$

Equation (43.4): Saikkonen (1991) model

$$\text{LIM}_t = -10.407 - 1.148 \text{LPM}_t + 1.247 \text{LTWGNP}_t$$

$$\begin{matrix} (-18.83) & (-6.40) & (35.47) \end{matrix}$$

$$+ 1.703 \Delta \text{LPM}_{t+1} + 1.803 \Delta \text{LPM}_t + 0.717 \Delta \text{LPM}_{t-1}$$

$$\begin{matrix} (3.48) & (3.59) & (1.41) \end{matrix}$$

$$- 0.342 \Delta \text{LTWGNP}_{t+1} + 0.056 \Delta \text{LTWGNP}_t - 0.680 \Delta \text{LTWGNP}_{t-1}$$

$$\begin{matrix} (-0.52) & (0.09) & (-1.02) \end{matrix}$$

$$\bar{R}^2 = 0.988 \quad \text{DW} = 1.873 \quad \text{Q}(6) = 3.605 \quad s = 0.089$$

Note: All variables are expressed in logarithms. LIM = import quantity; LPM = relative import price; LTWGNP = Taiwan real GNP; and ECM = error correction term. *t* statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and *s* = standard error of the estimate.

Table 17

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 Estimation of trade balance of Taiwan with the U.S., annual data 1965–1994
 

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Equation (44.1): cointegrating regression model

$$\text{LB\_US}_t = -12.621 + 1.856 \text{LQUS}_t + 1.470 \text{LUSGNP}_t - 0.612 \text{LTWGNP}_t + 0.0392 \text{AIP}_t$$

$$\bar{R}^2 = 0.699 \quad \text{DW} = 0.846 \quad \text{Q}(7) = 28.65 \quad s = 0.238$$

Equation (44.2): error correction model

$$\begin{aligned} \Delta \text{LB\_US}_t = & -0.316 \text{ECM}_{t-1} + 0.601 \Delta \text{LQUS}_t + 1.095 \Delta \text{LQUS}_{t-1} + 1.619 \Delta \text{LUSGNP}_t \\ & (-1.64) \quad (1.31) \quad (1.97) \quad (0.82) \\ & -0.503 \Delta \text{LTWGNP}_t + 0.0322 \Delta \text{AIP}_t \\ & (-0.64) \quad (1.94) \end{aligned}$$

$$\bar{R}^2 = 0.495 \quad \text{DW} = 1.705 \quad \text{Q}(7) = 5.79 \quad s = 0.164$$

Equation (44.3): difference regression model

$$\begin{aligned} \Delta \text{LB\_US}_t = & 0.766 \Delta \text{LQUS}_t + 1.640 \Delta \text{LQUS}_{t-1} + 1.002 \Delta \text{LUSGNP}_t \\ & (1.65) \quad (3.55) \quad (0.50) \\ & -0.484 \Delta \text{LTWGNP}_t + 0.0377 \Delta \text{AIP}_t \\ & (-0.59) \quad (2.24) \end{aligned}$$

$$\bar{R}^2 = 0.458 \quad \text{DW} = 2.180 \quad \text{Q}(7) = 8.10 \quad s = 0.169$$

Equation (44.4): Saikkonen (1991) model

$$\begin{aligned} \text{LB\_US}_t = & -7.372 + 2.563 \text{LQUS}_t - 1.492 \text{LUSGNP}_t + 0.429 \text{LTWGNP}_t + 0.052 \text{AIP}_t \\ & (-0.27) \quad (2.47) \quad (-0.22) \quad (0.20) \quad (1.51) \\ & + 0.506 \Delta \text{LQUS}_{t+1} - 2.723 \Delta \text{LQUS}_t - 1.347 \Delta \text{LQUS}_{t-1} \\ & (0.64) \quad (-3.32) \quad (-1.49) \\ & - 2.456 \Delta \text{LUSGNP}_{t+1} + 2.725 \Delta \text{LUSGNP}_t + 1.700 \Delta \text{LUSGNP}_{t-1} \\ & (-0.51) \quad (0.65) \quad (0.50) \\ & + 4.627 \Delta \text{LTWGNP}_{t+1} + 2.233 \Delta \text{LTWGNP}_t - 0.500 \Delta \text{LTWGNP}_{t-1} \\ & (1.81) \quad (0.91) \quad (-0.50) \\ & + 0.012 \Delta \text{AIP}_{t+1} + 0.035 \Delta \text{AIP}_t + 0.0004 \Delta \text{AIP}_{t-1} \\ & (0.21) \quad (0.66) \quad (0.008) \end{aligned}$$

$$\bar{R}^2 = 0.811 \quad \text{DW} = 1.558 \quad \text{Q}(6) = 3.51 \quad s = 0.155$$

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 Note: All variables are expressed in logarithms. LB\_US = trade balance of Taiwan with the U.S.; LQUS = real exchange rate of the New Taiwan dollar against the U.S. dollar; LUSGNP = U.S. real GDP; LTWGNP = Taiwan real GNP; AIP = degree of industrialization of Taiwan (determined as the ratio of Taiwan industrial production exports to total exports); and ECM = error correction term. t statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and s = standard error of the estimate.
 

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Table 18

Estimation of trade balance of Taiwan with Japan, annual data 1965–1994

Equation (45.1): cointegrating regression model

$$LB\_J_t = 4.914 + 0.614 LQJ_t - 1.539 LJGNP_t + 1.002 LTWGNP_t$$

$$\bar{R}^2 = 0.340 \quad DW = 1.232 \quad Q(7) = 10.02 \quad s = 0.173$$

Equation (45.2): error correction model

$$\Delta LB\_J_t = -0.636 ECM_{t-1} + 0.358 \Delta LQJ_t - 0.880 \Delta LJGNP_t + 0.535 \Delta LTWGNP_t$$

(-3.32)                    (1.29)                    (-0.84)                    (0.76)

$$\bar{R}^2 = 0.253 \quad DW = 1.850 \quad Q(7) = 7.73 \quad s = 0.158$$

Equation (45.3): difference regression model

$$\Delta LB\_J_t = 0.324 \Delta LQJ_t - 0.387 \Delta LJGNP_t + 0.272 \Delta LTWGNP_t$$

(1.00)                    (-0.32)                    (0.33)

$$\bar{R}^2 = 0.03 \quad DW = 2.411 \quad Q(7) = 11.58 \quad s = 0.186$$

Equation (45.4): Saikkonen (1991) model

$$LB\_J_t = 1.015 + 1.144 LQJ_t - 0.811 LJGNP_t + 0.697 LTWGNP_t$$

(0.14)                    (1.43)                    (-0.60)                    (1.05)

$$+ 0.193 \Delta LQJ_{t+1} - 0.671 \Delta LQJ_t - 0.358 \Delta LQJ_{t-1}$$

(0.38)                    (-1.33)                    (-0.82)

$$- 3.051 \Delta LJGNP_{t+1} + 3.284 \Delta LJGNP_t - 1.051 \Delta LJGNP_{t-1}$$

(-1.18)                    (1.82)                    (-0.55)

$$+ 0.021 \Delta LTWGNP_{t+1} + 0.182 \Delta LTWGNP_t + 0.308 \Delta LTWGNP_{t-1}$$

(0.01)                    (0.11)                    (0.19)

$$\bar{R}^2 = 0.480 \quad DW = 0.843 \quad Q(6) = 29.27 \quad s = 0.153$$

Note: All variables are expressed in logarithms. LB\_J = trade balance of Taiwan with Japan; LQJ = real exchange rate of the New Taiwan dollar against Japanese yen; LJGNP = Japan real GNP; LTWGNP = Taiwan real GNP; and ECM = error correction term. t statistics are in parentheses;  $\Delta$  = difference operator;  $\bar{R}^2$  = adjusted  $R^2$  statistic; DW = Durbin-Watson statistic; Q = Ljung-Box Q-statistic; and s = standard error of the estimate.

Table 19

## The summations of price elasticities

(1)	(2)	(3)	(4)	(5)
Summation of price elasticities	Cointegrating regression model	Saikkonen (1991) model	Error correction model	First difference model
<u>Taiwan-U.S. bilateral trade:</u>				
(a) Trade balance improvement effect	2.034	3.645	0.172	0.493
(b) Supply shock effect	0.009	-0.238	0.522	0.498
(c) = (a) + (b) - 1	1.043	2.407	-0.306	-0.009
(d) Reduced-form equation	1.856	2.563	0.601	0.766
<u>Taiwan-Japan bilateral trade:</u>				
(e) Trade balance improvement effect	1.530	2.661	-0.272	0.648
(f) Supply shock effect	0.190	-0.297	0.580	0.652
(g) = (e) + (f) - 1	0.720	1.364	-0.692	0.300
(h) Reduced-form equation	0.614	1.144	0.358	0.324

APPENDIX B: FIGURES

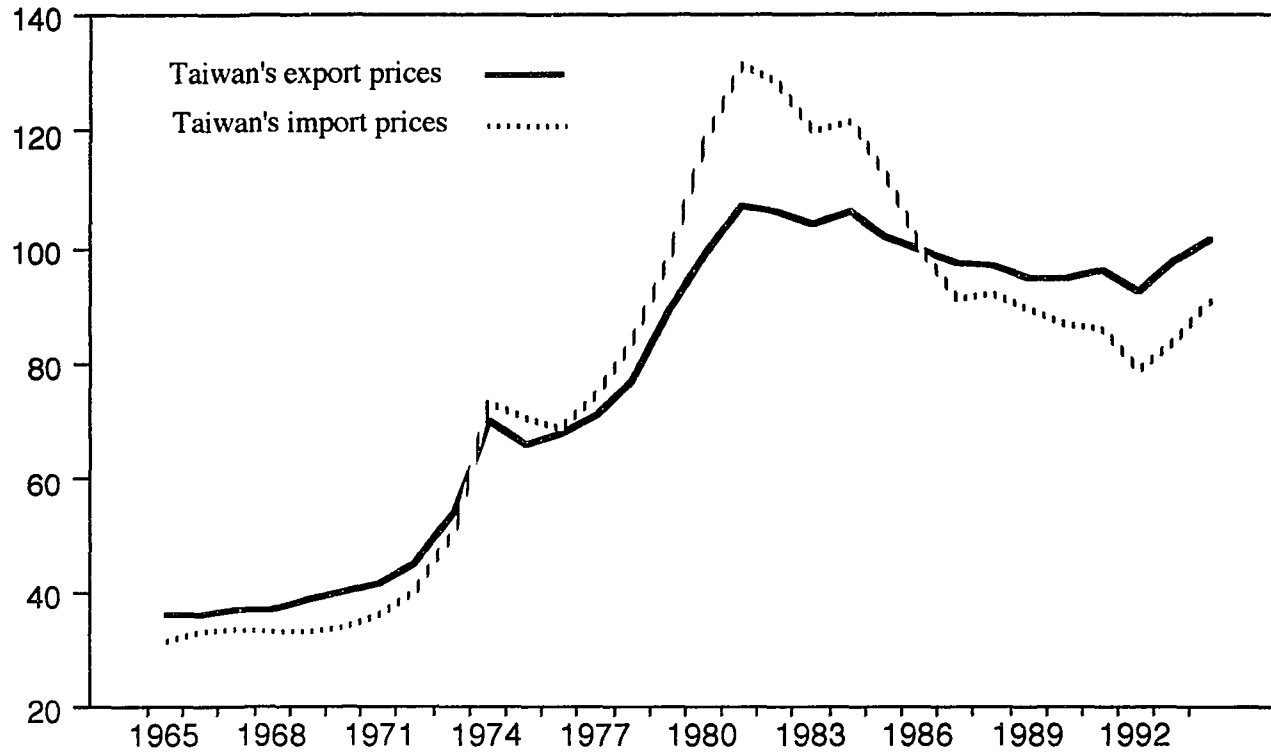


Figure 1. Taiwan's export and import prices indexes, 1965-1994, 1986=100. Export prices are the unit values of exports. Import prices are the unit values of imports.

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

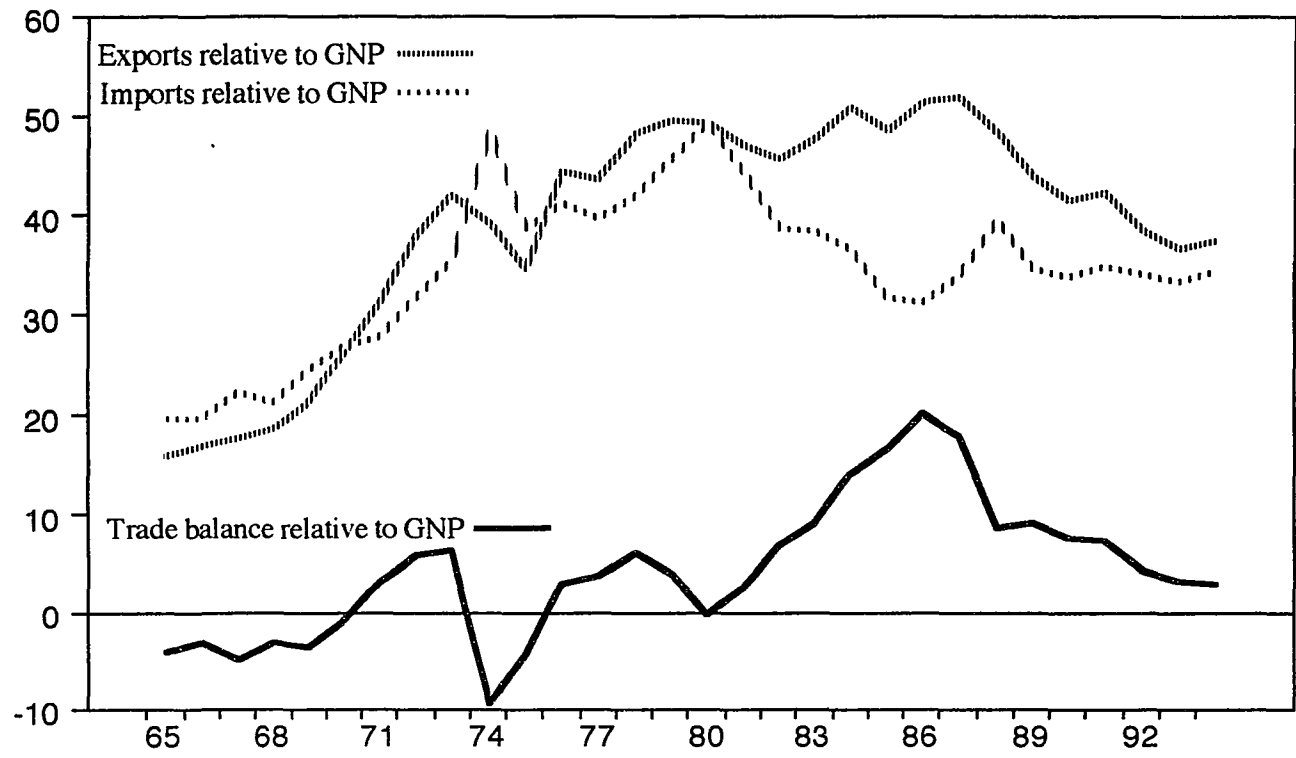


Figure 2. Taiwan's exports, imports, and trade balances relative to GNP (percentage), 1965-1994.

Source: Taiwan statistical data book.

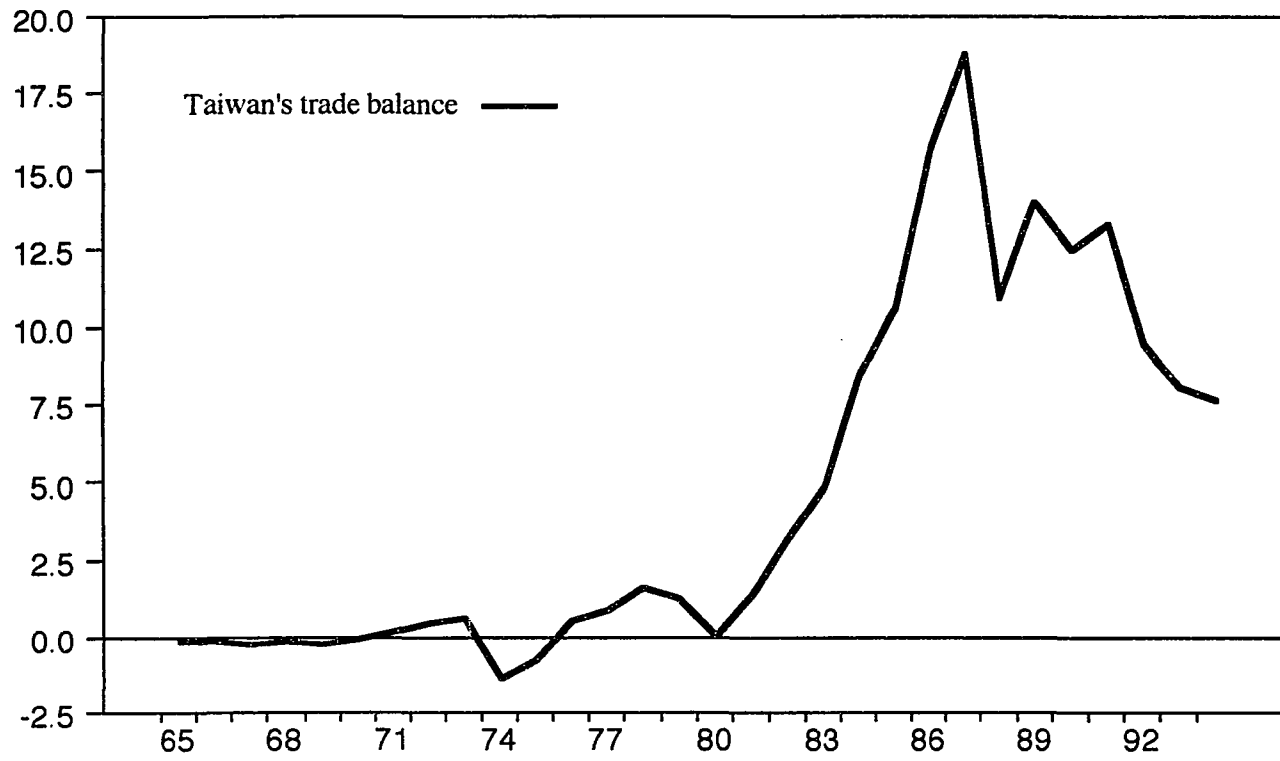


Figure 3. Taiwan's trade balance, 1965-1994, billions of U.S. dollars

Source: Taiwan statistical data book.

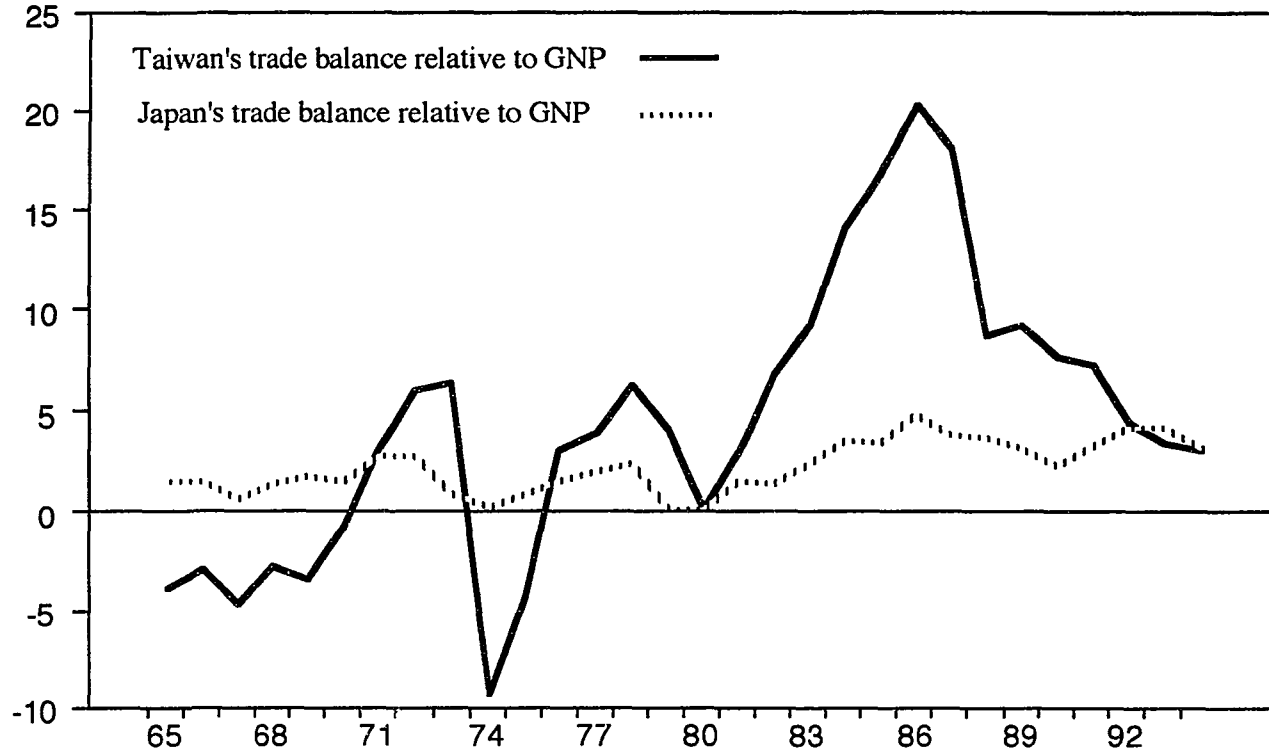


Figure 4. The percentages of Taiwan's and Japan's trade balances relative to their GNPs, 1965-1994, percentage.

Source: International Financial Statistics, IMF and Taiwan statistical data book.

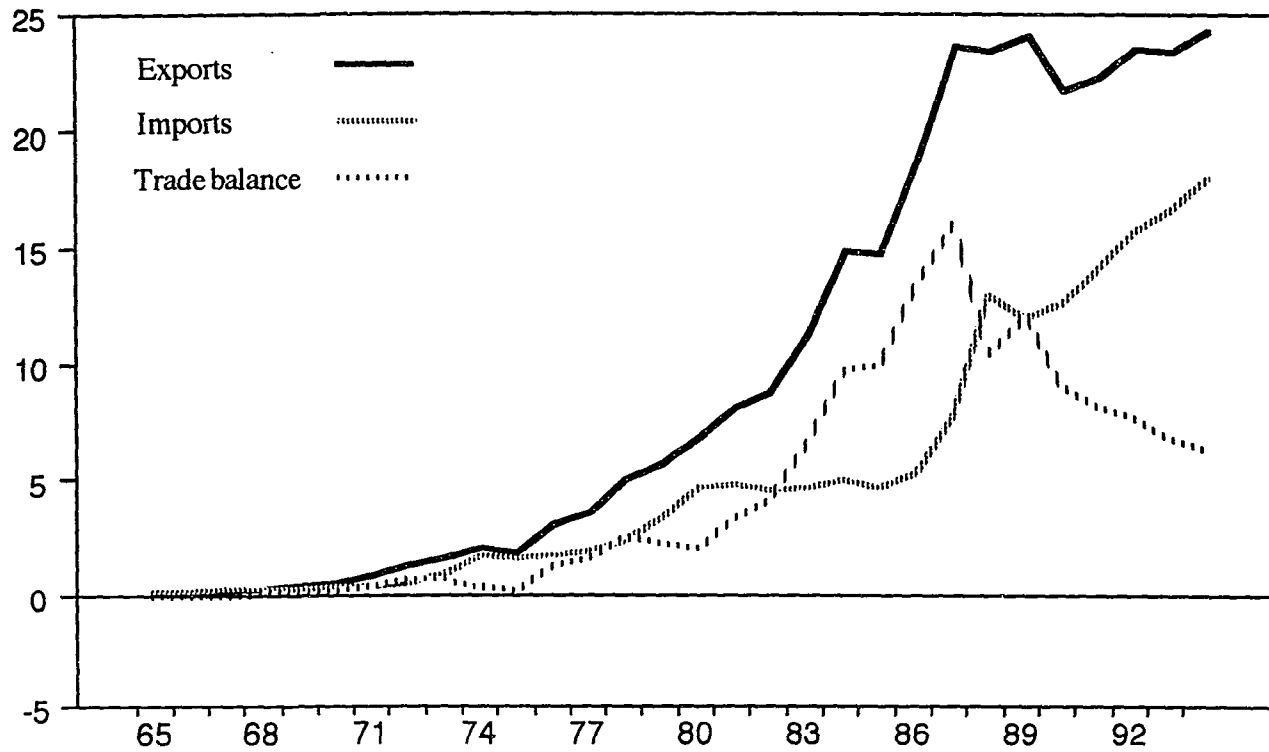


Figure 5. The values of Taiwan exports to and imports from the United States, and the trade balance of Taiwan with the United States, 1965-1994, billions of U.S. dollars

Source: Taiwan statistical data book.

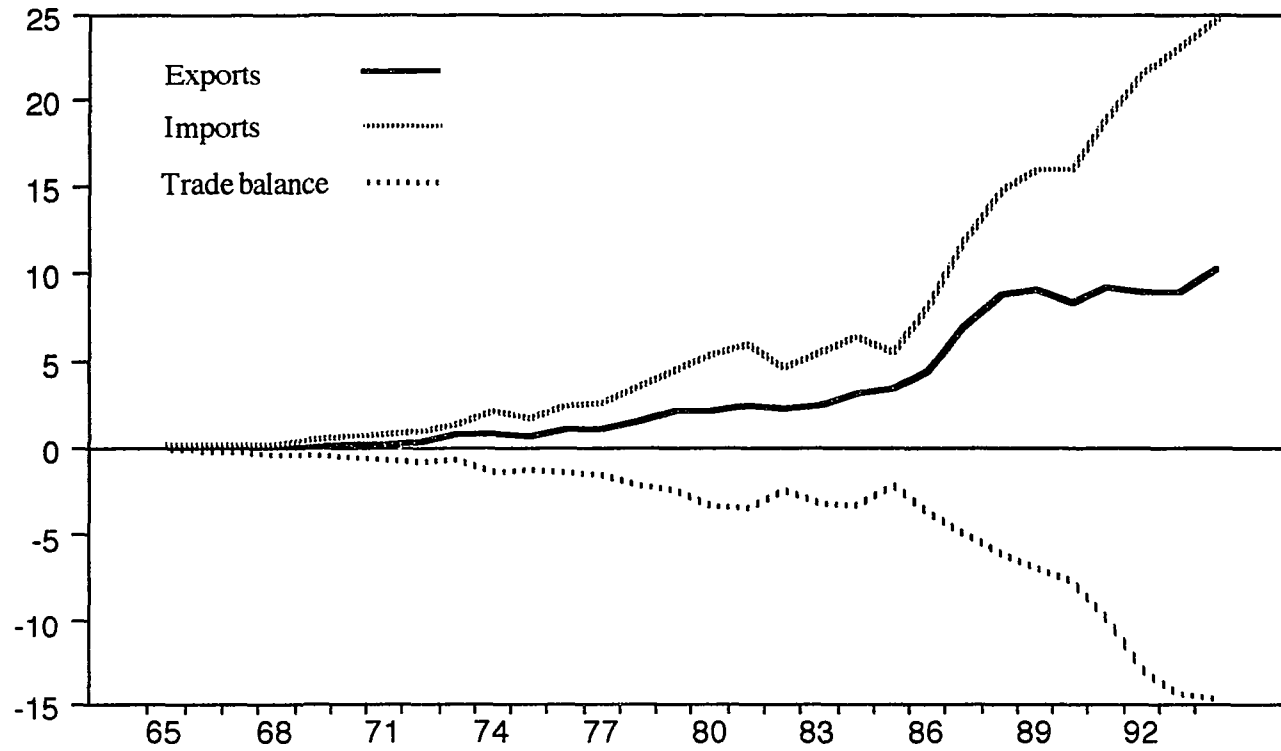


Figure 6. The values of Taiwan exports to and imports from Japan, and the trade balance of Taiwan with Japan, 1965-1994, billions of U.S. dollars.

Source: Taiwan statistical data book.

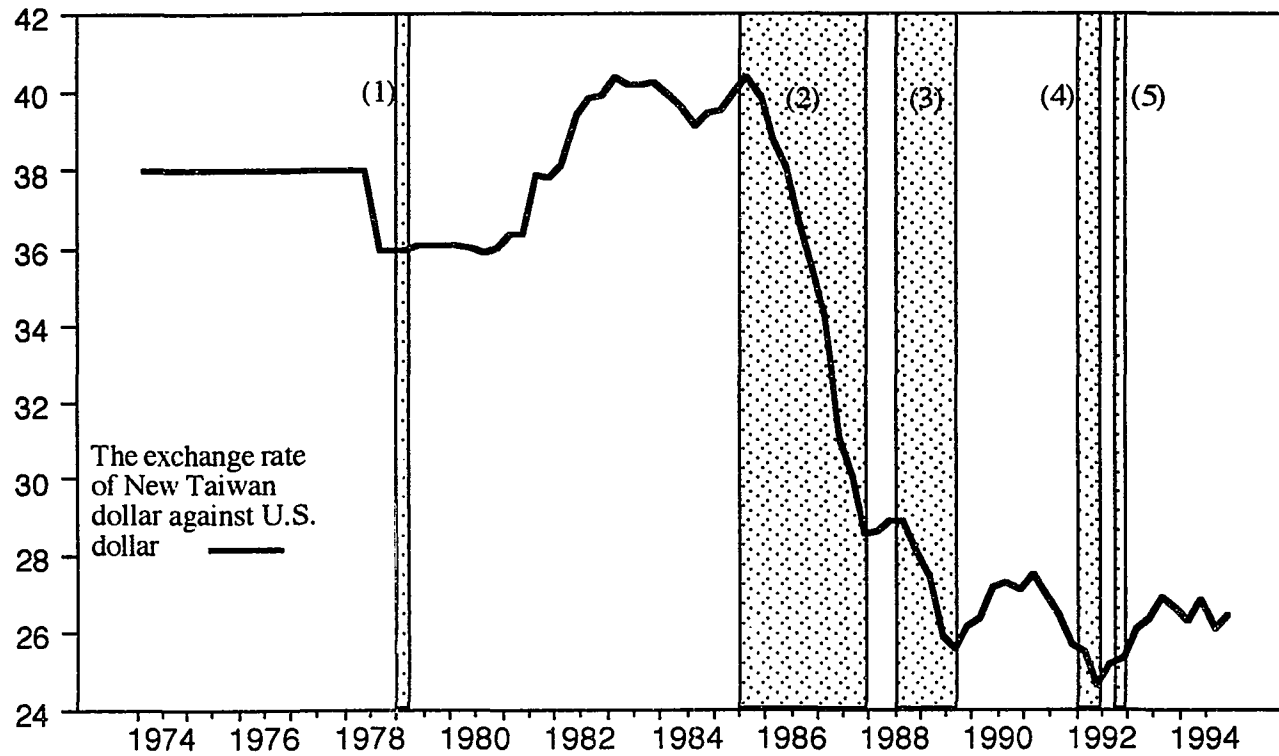


Figure 7. The exchange rate of New Taiwan dollar against U.S. dollar, units of New Taiwan dollar per U.S. dollar, 1974 first quarter to 1994 fourth quarter.

Source: Financial Statistics, Taiwan District, Republic of China.

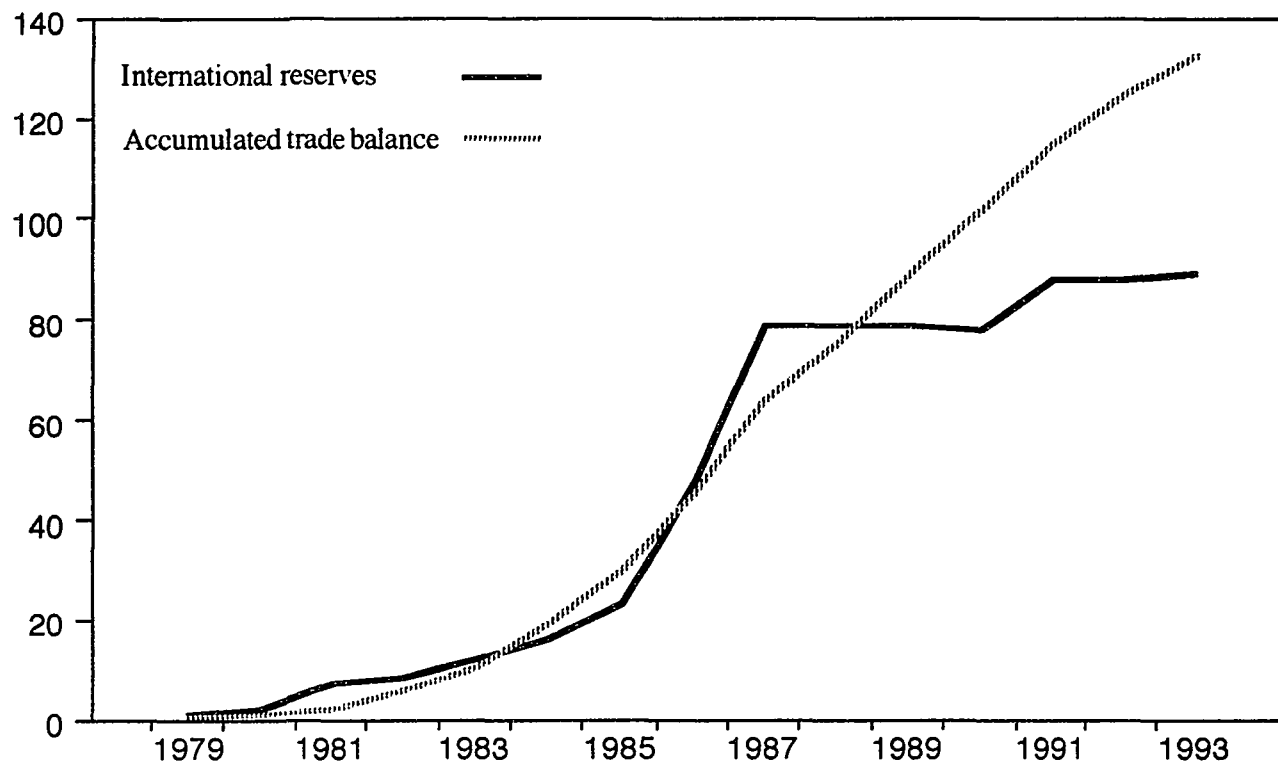


Figure 8. Taiwan's international reserves and accumulated trade balances, 1979-1993, billions of U.S. dollars.

Source: Taiwan statistical data book and Financial Statistics, Taiwan District, Republic of China.

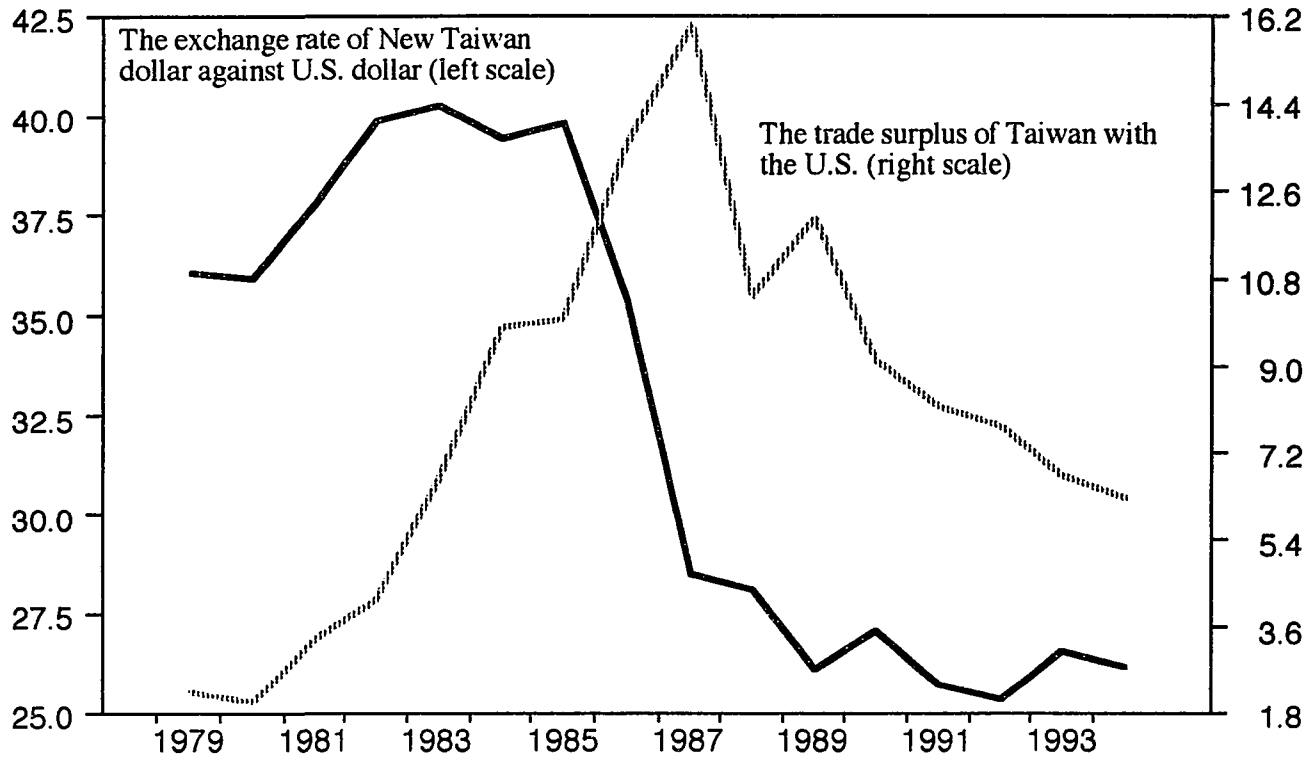


Figure 9. The exchange rate of the New Taiwan dollar against U.S. dollar and Taiwan's trade surplus with the U.S., 1979-1994, units of New Taiwan dollar per U.S. dollar, billions of U.S. dollars.

Source: Taiwan statistical data book and Financial Statistics, Taiwan District, Republic of China.

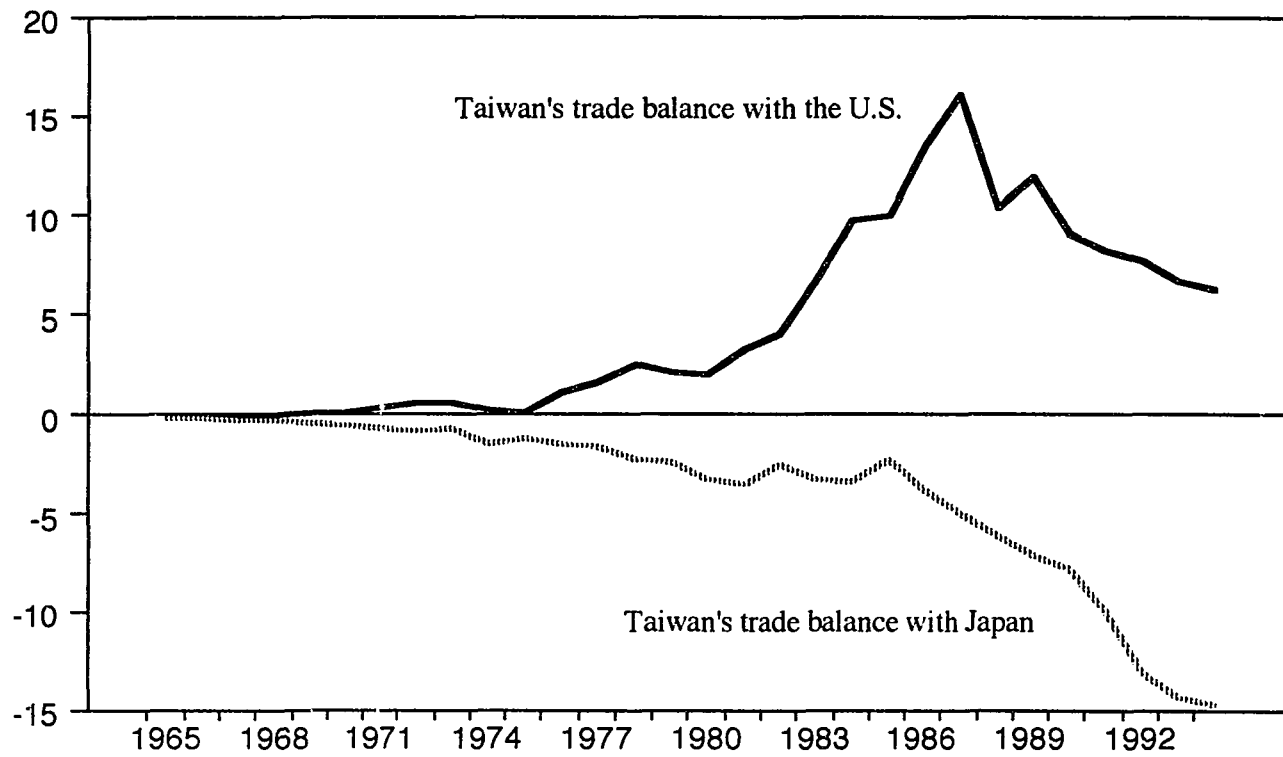


Figure 10. The trade balances of Taiwan with the U.S. and Japan, 1965-1994, billions of U.S. dollars

Source: Taiwan statistical data book.

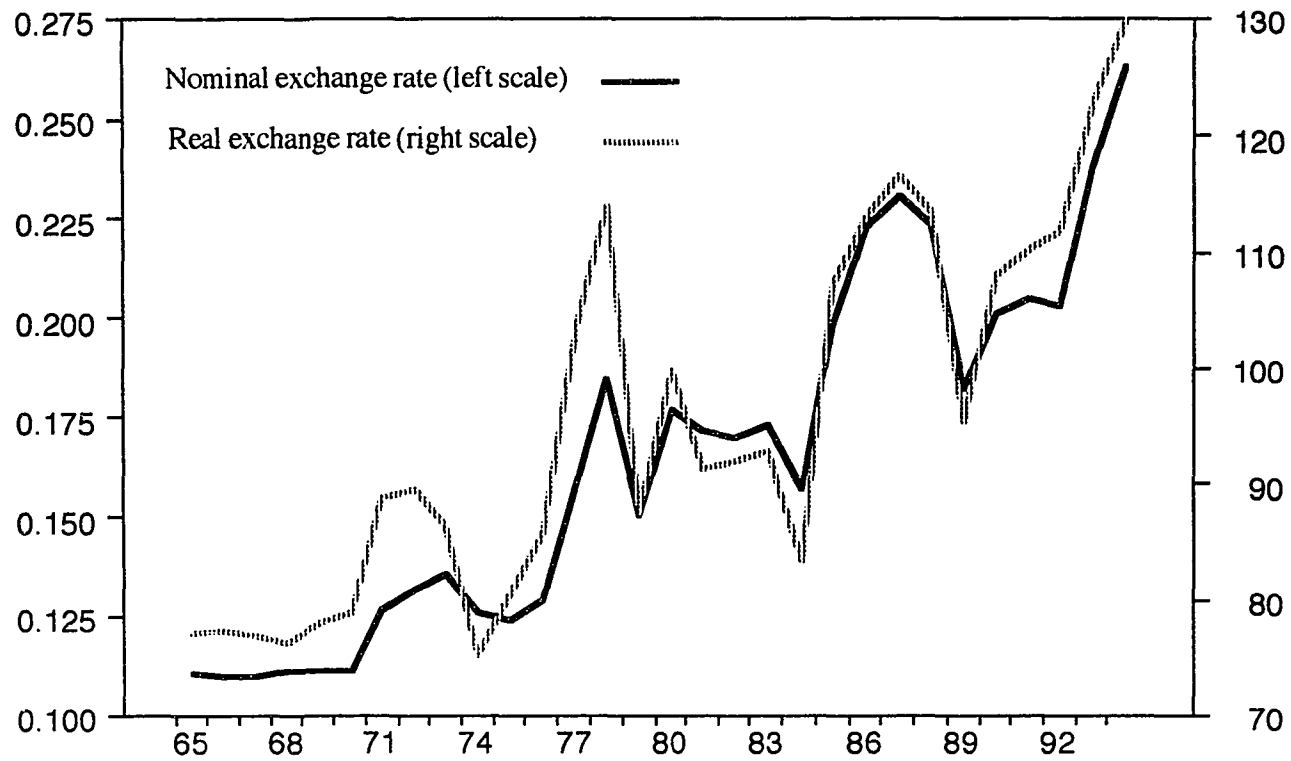


Figure 11. The nominal and real exchange rates of the New Taiwan dollar against Japanese yen, 1965-1994, New Taiwan dollar per Japanese yen, 1980=100.

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

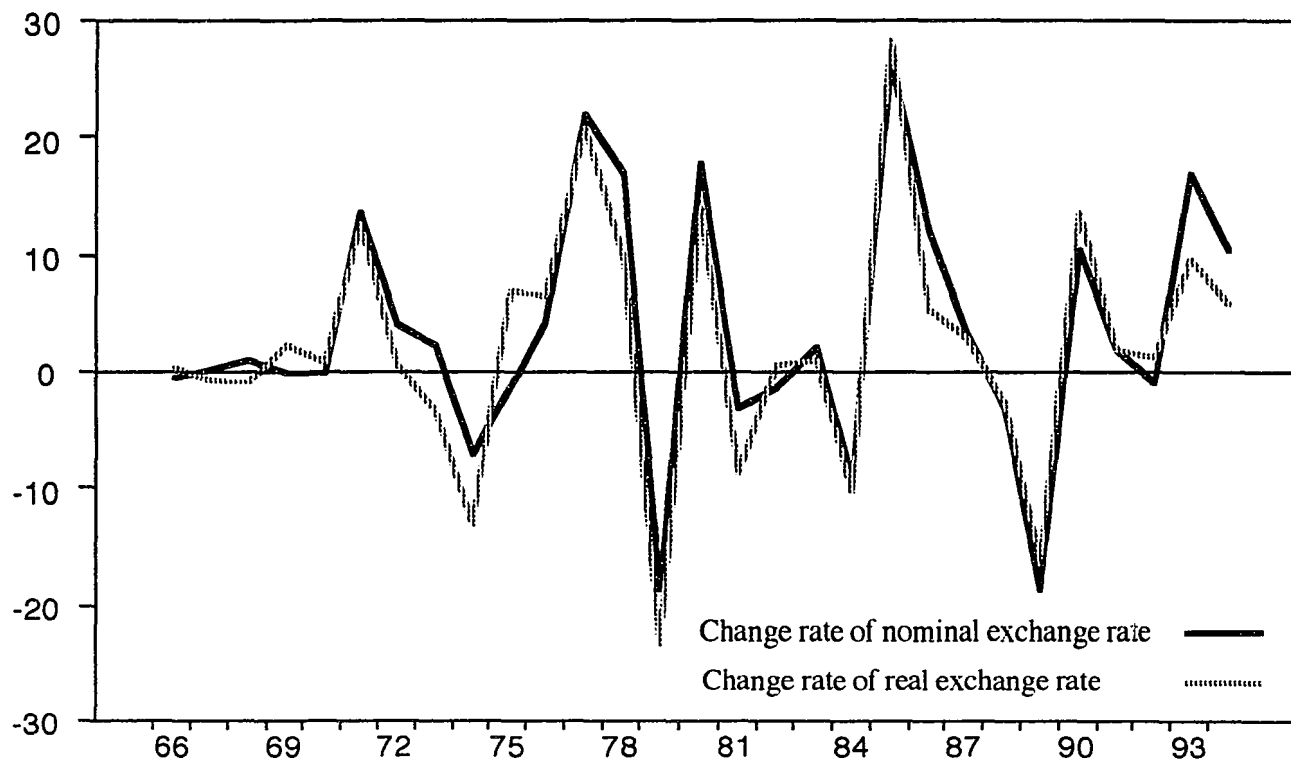


Figure 12. The change rates of the nominal and real exchange rates of the New Taiwan dollar against Japanese yen, 1965-1994, (percentage).

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

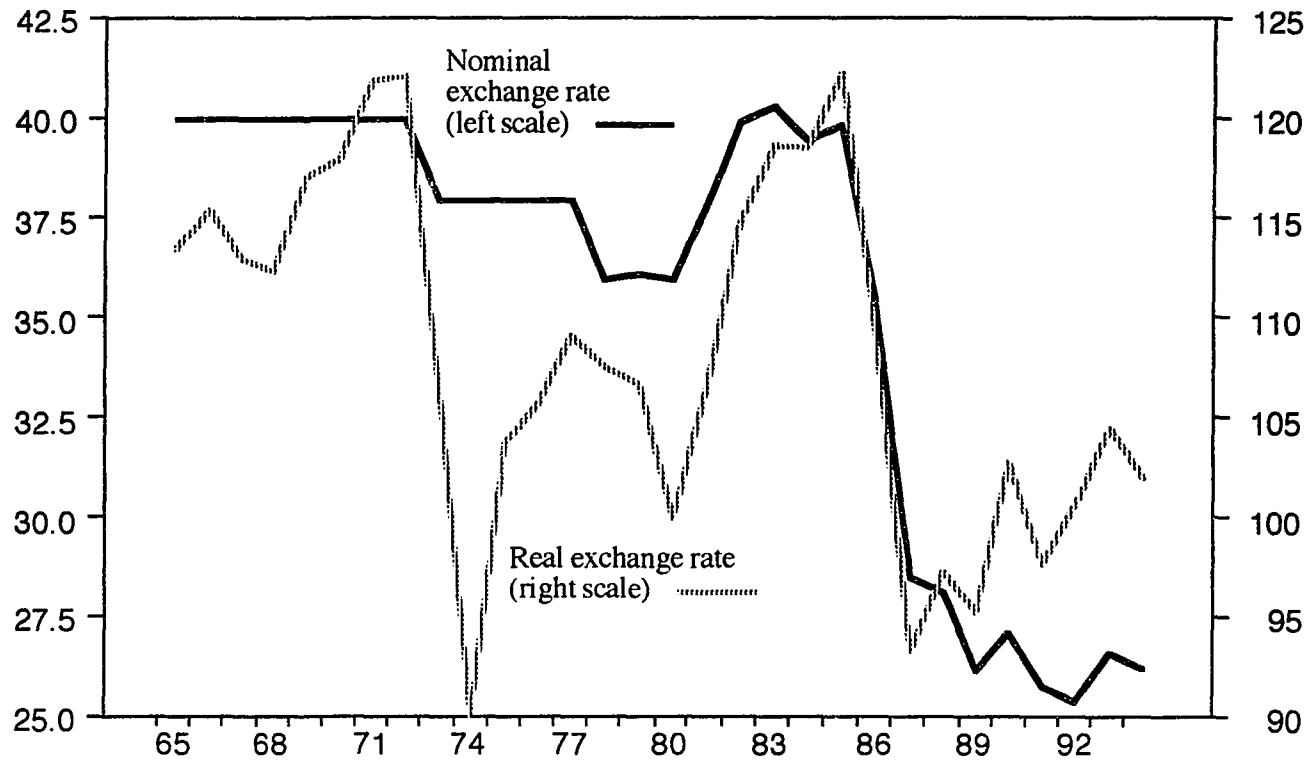


Figure 13. The nominal and real exchange rates of the New Taiwan dollar against U.S. dollar, 1965-1994, New Taiwan dollar per U.S. dollar, 1980=100.

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

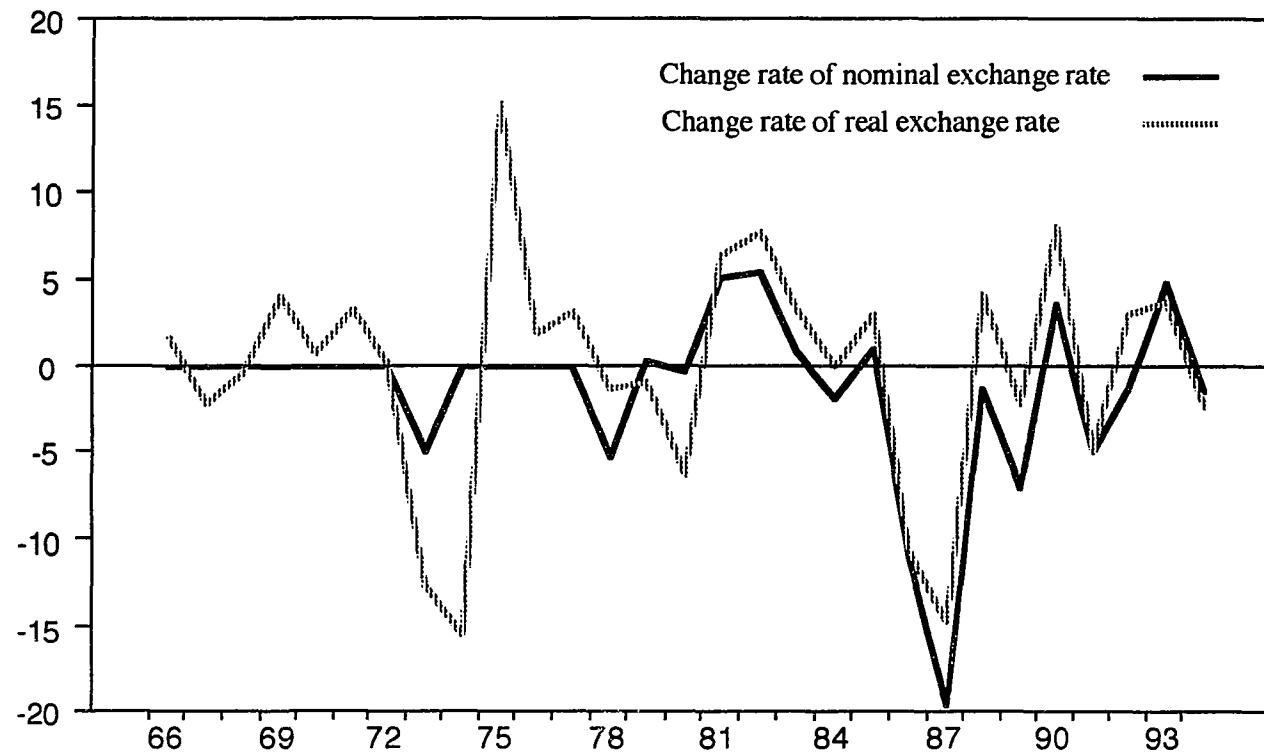


Figure 14. The change rates of the nominal and real exchange rates of the New Taiwan dollar against U.S. dollar, 1965-1994, (percentage).

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

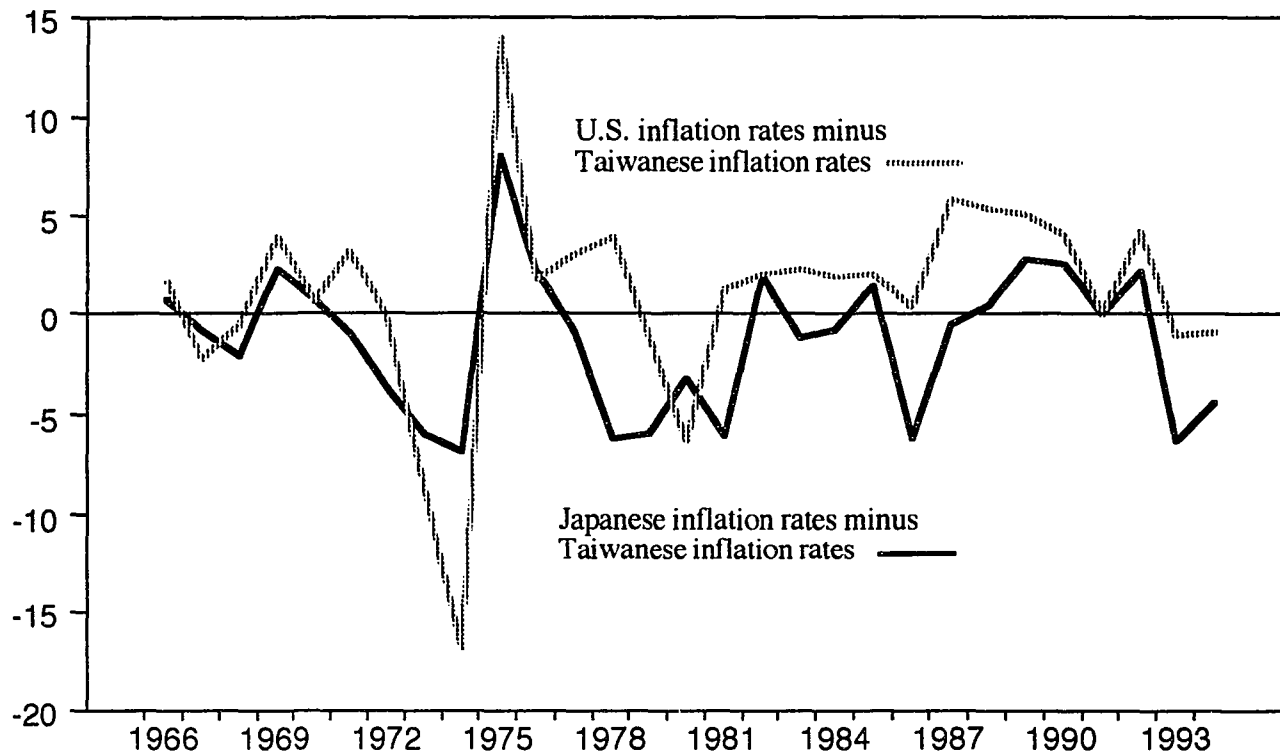


Figure 15. The differences between the inflation rates of Taiwan and Japan and these of Taiwan and the U.S., 1966-1994, (percentage).

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

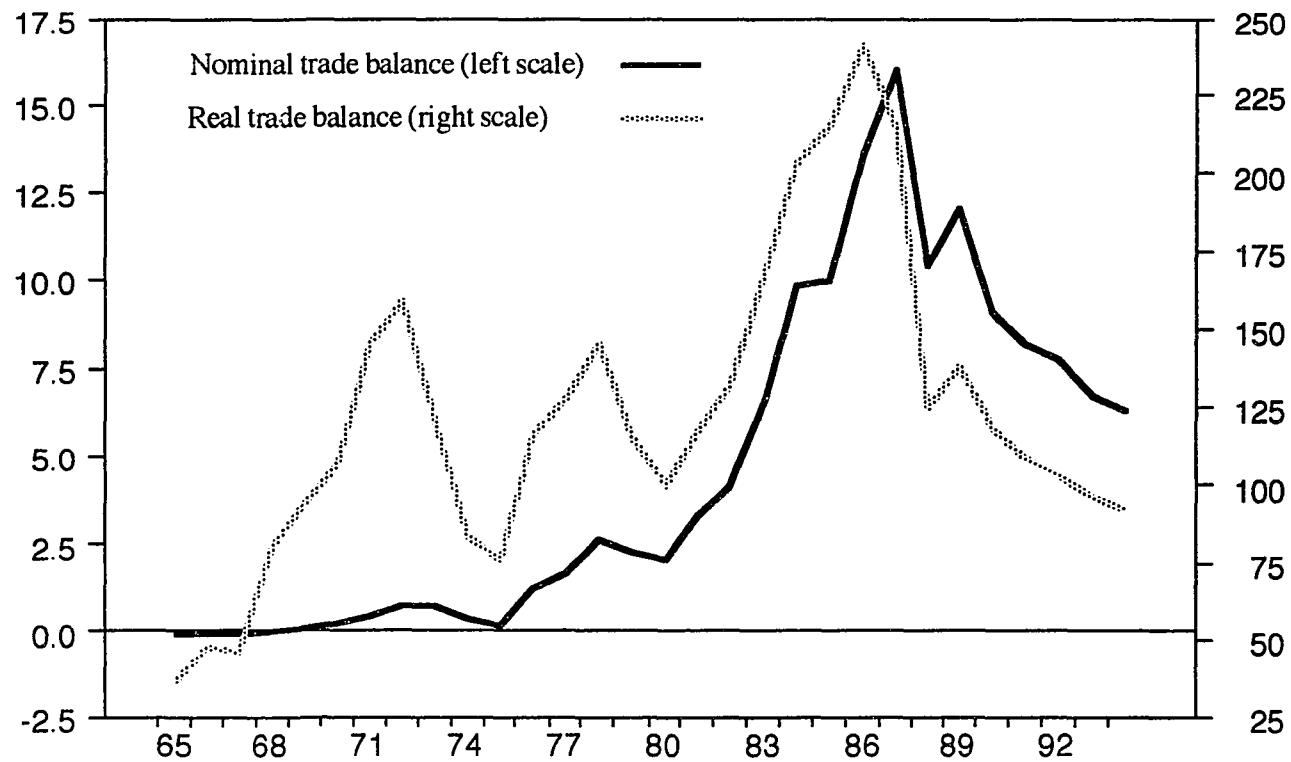


Figure 16. The nominal and real trade balance of Taiwan with the U.S., 1965-1994, billions of U.S. dollars, 1980=100

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

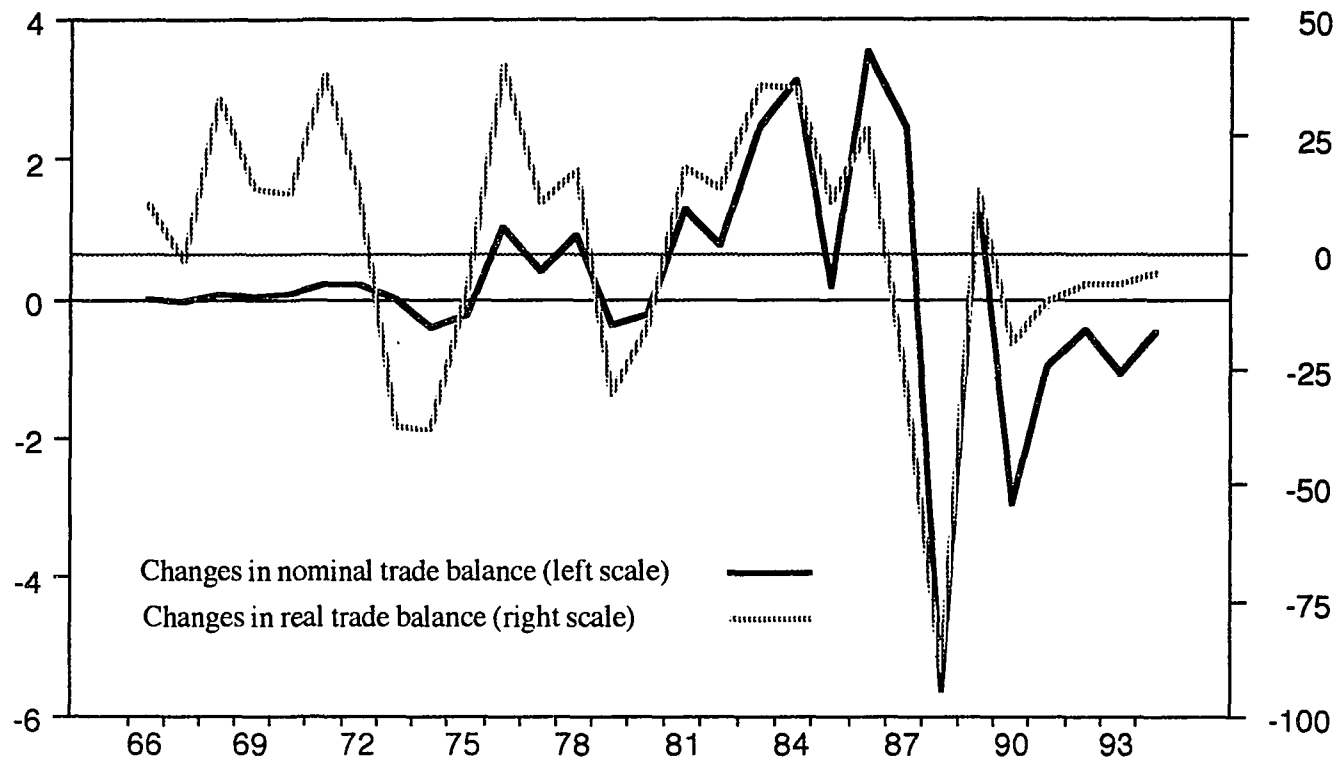


Figure 17. The change rates of the nominal and real trade balances of Taiwan with the U.S., 1965-1994.

Source: International Financial Statistics, IMF and Financial Statistics, Taiwan District, Republic of China.

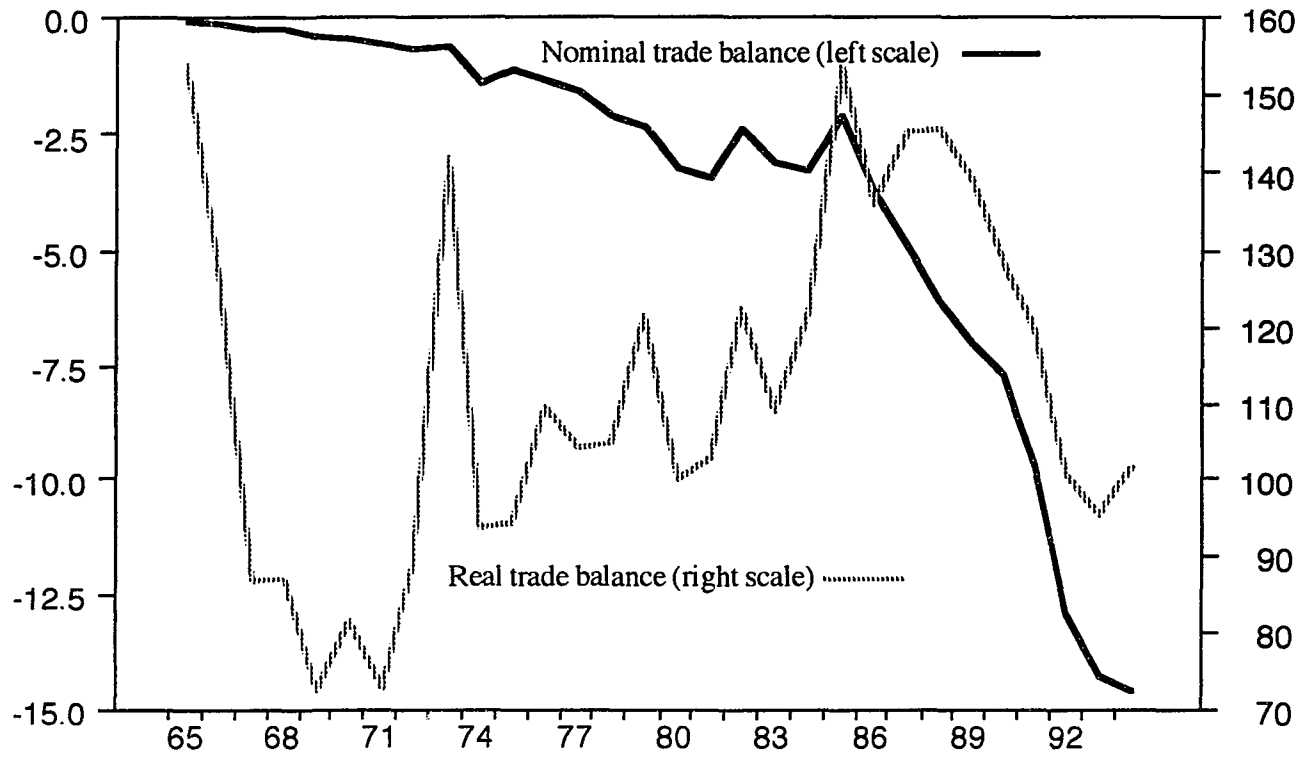


Figure 18. The nominal and real trade balance of Taiwan with Japan, 1965-1994, billions of U.S. dollars, 1980=100.

Source: Taiwan statistical data book and Financial Statistics, Taiwan District, Republic of China.

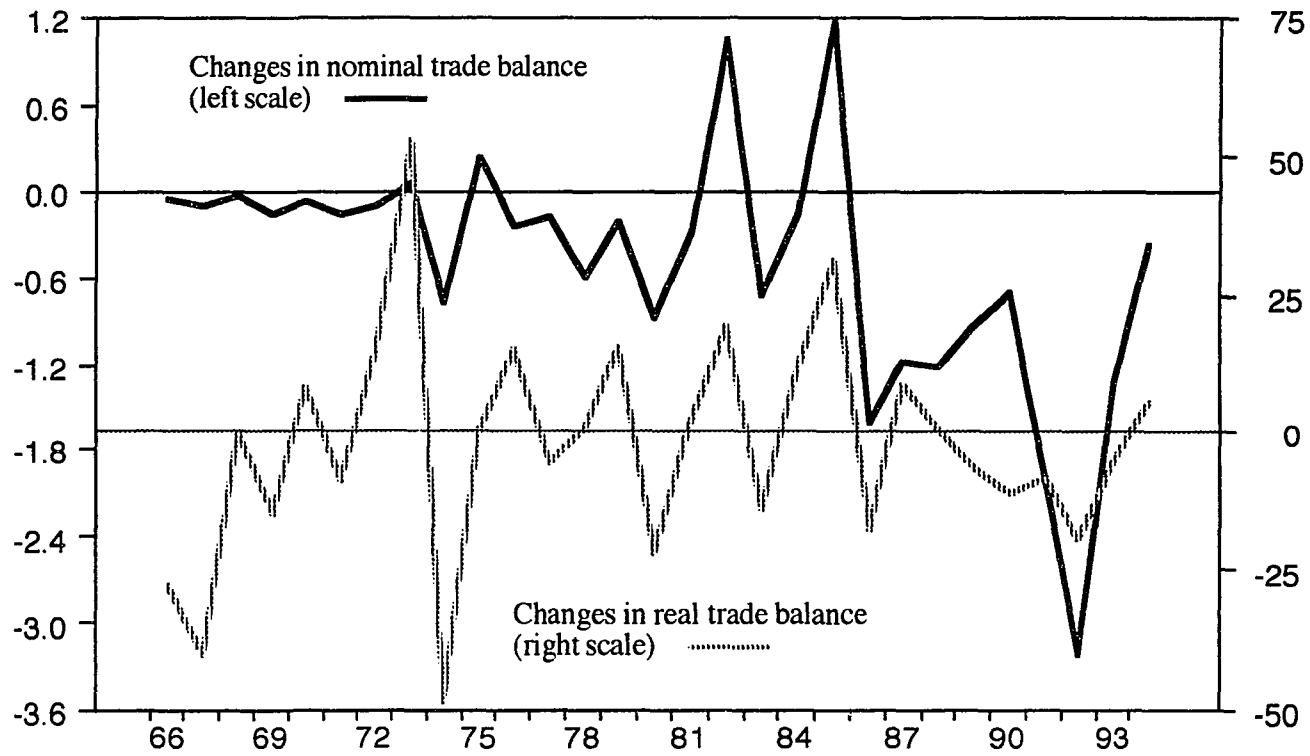


Figure 19. The changes of the nominal and real trade balances of Taiwan with Japan, 1965-1994, billions of U.S. dollars.

Source: Taiwan statistical data book and Financial Statistics, Taiwan District, Republic of China.

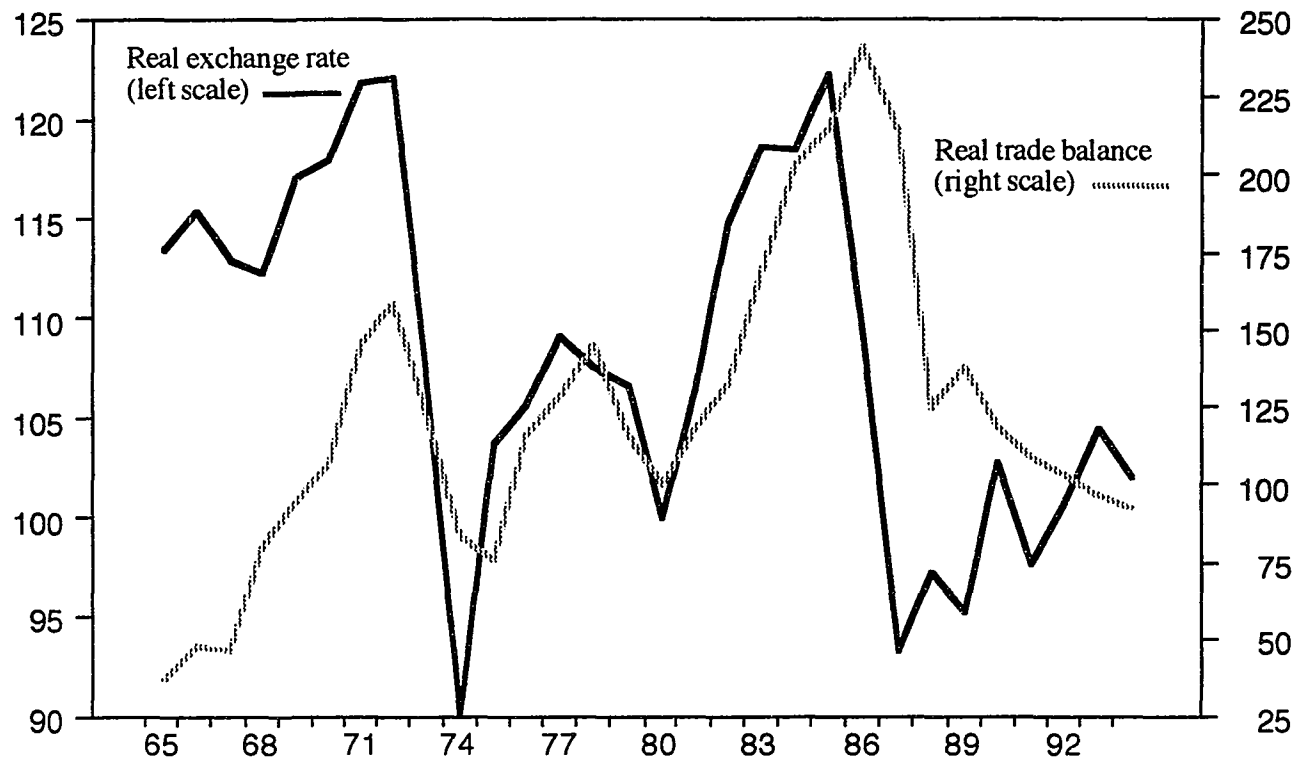


Figure 20. Taiwan's real exchange rate and real trade balance with the United States, 1965-1994, 1980=100.

Source: International Financial Statistics, IMF, Taiwan statistical data book, and Financial Statistics, Taiwan District, Republic of China.

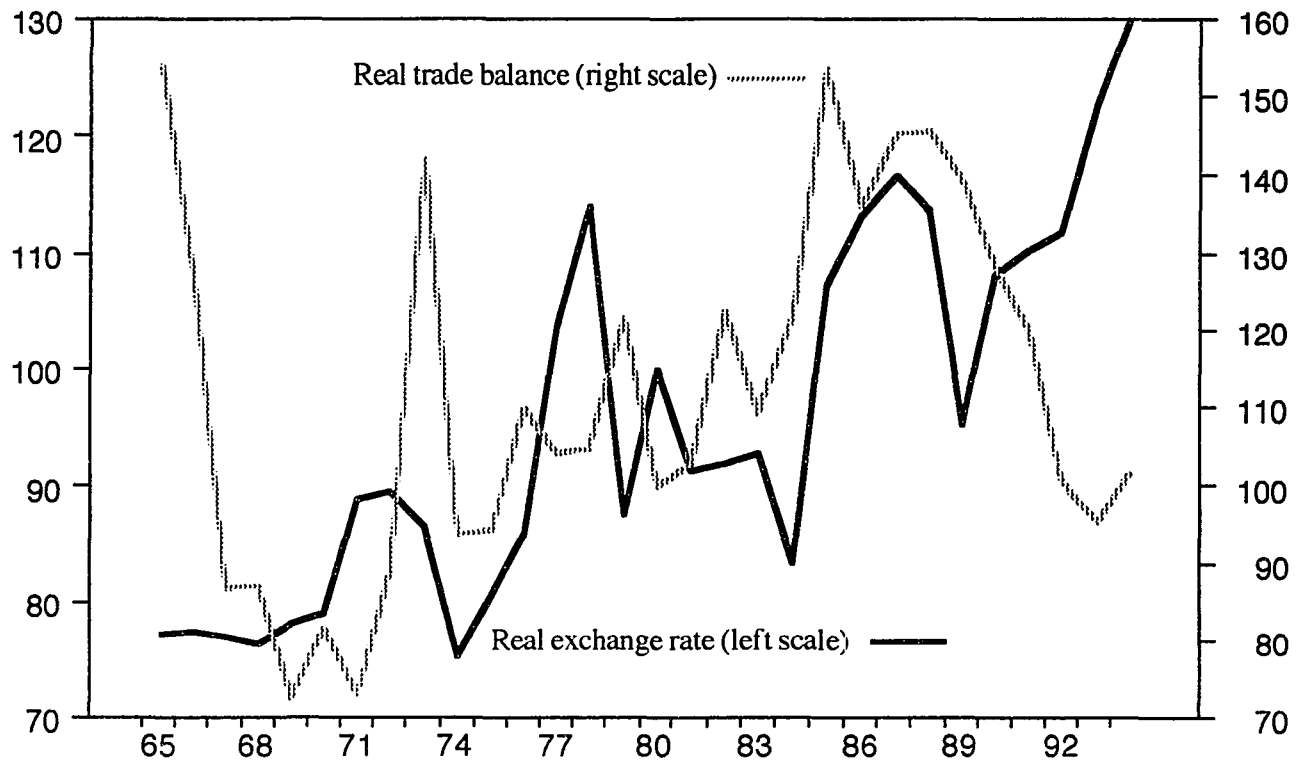
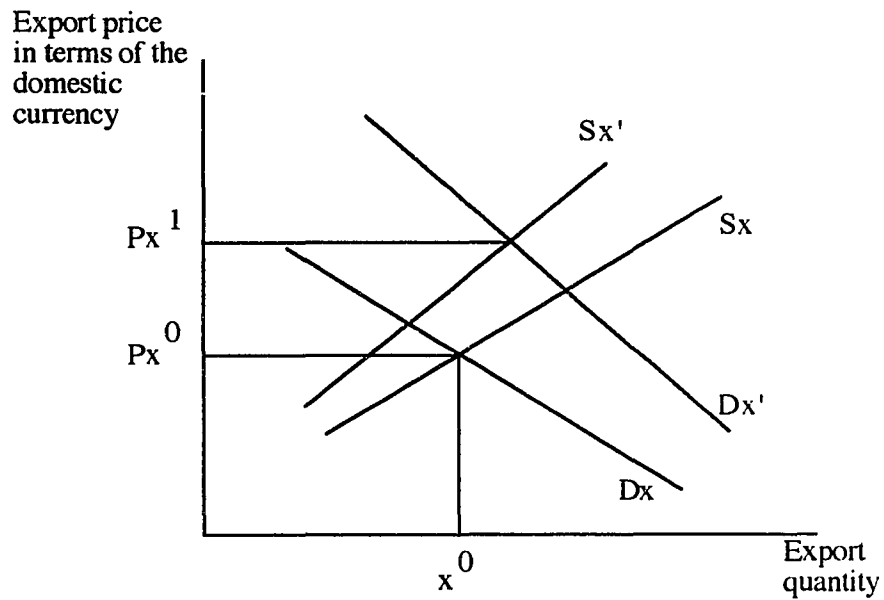
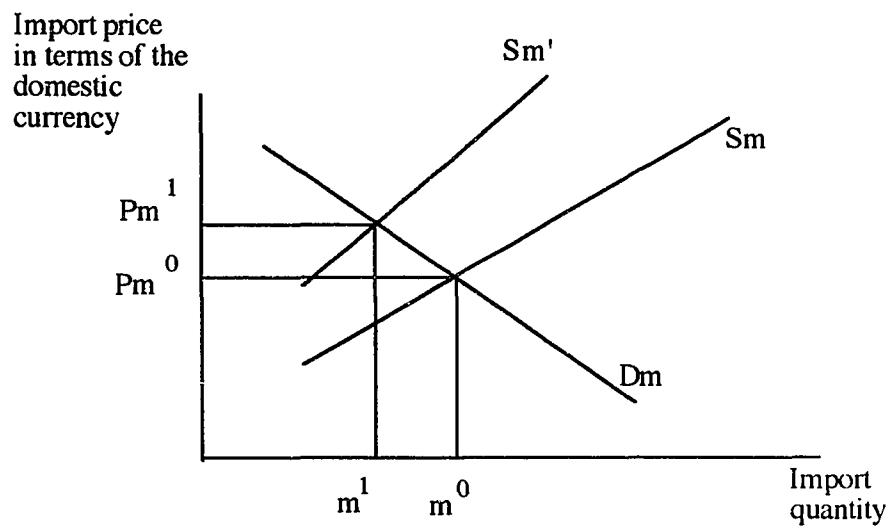


Figure 21. Taiwan's real exchange rate and real trade balance with Japan, 1965-1994, 1980=100.

Source: International Financial Statistics, IMF, Taiwan statistical data book, and Financial Statistics, Taiwan District, Republic of China.

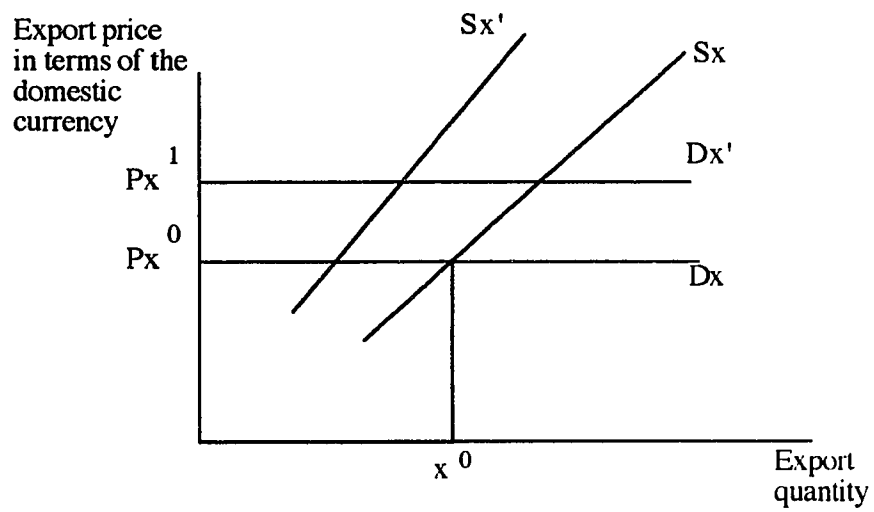


(a) Export market

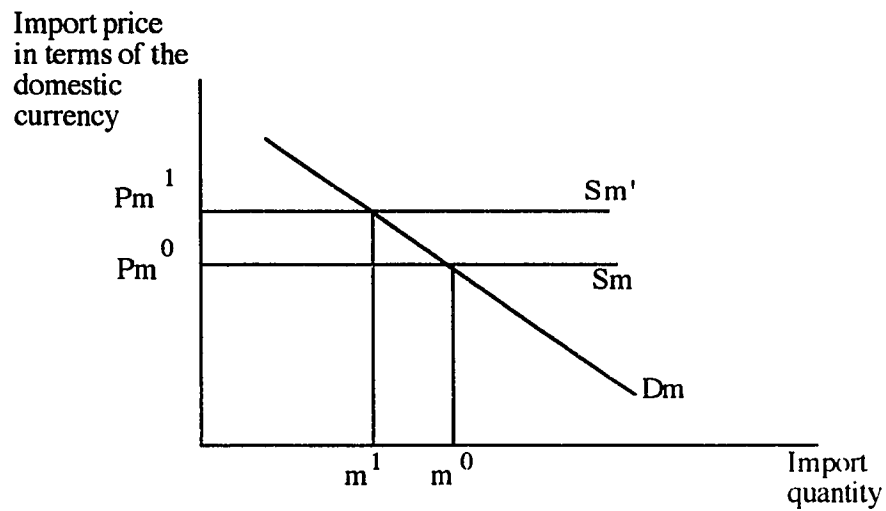


(b) Import market

Figure 22. The effect of a devaluation on the trade balance of a large country is ambiguous in the modified Bickerdike-Robinson-Metzler model



(a) Export market



(b) Import market

Figure 23. The effect of a devaluation on the trade balance of a small country is ambiguous in the modified Bickerdike-Robinson-Metzler model

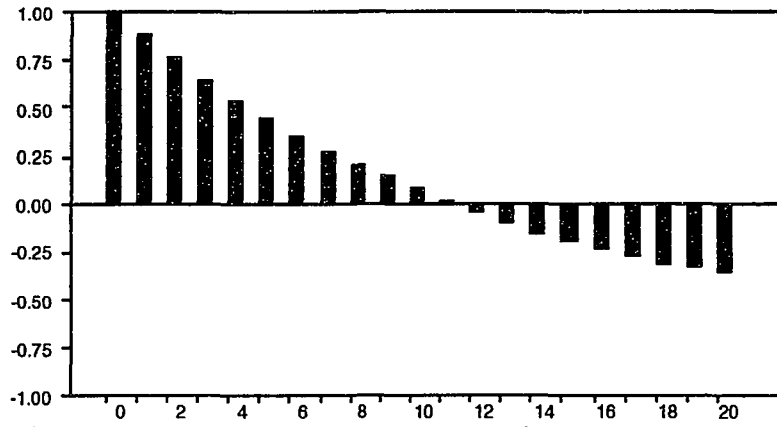


Figure 24. Correlogram of the logarithm of Japan's real GNP

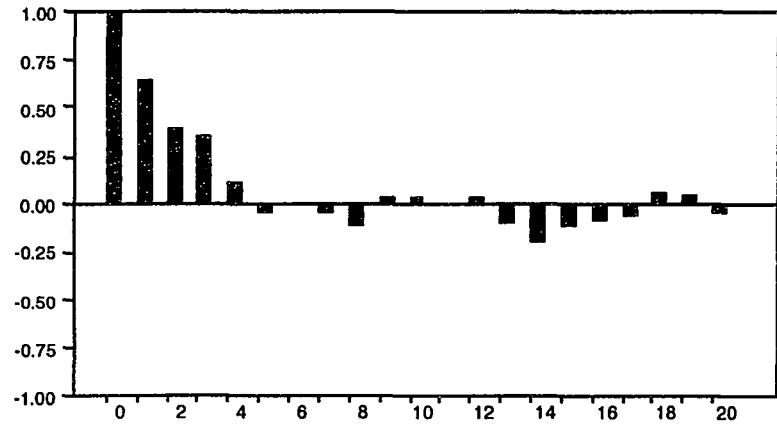


Figure 25. Correlogram of the first difference of the log of Japan's real GNP

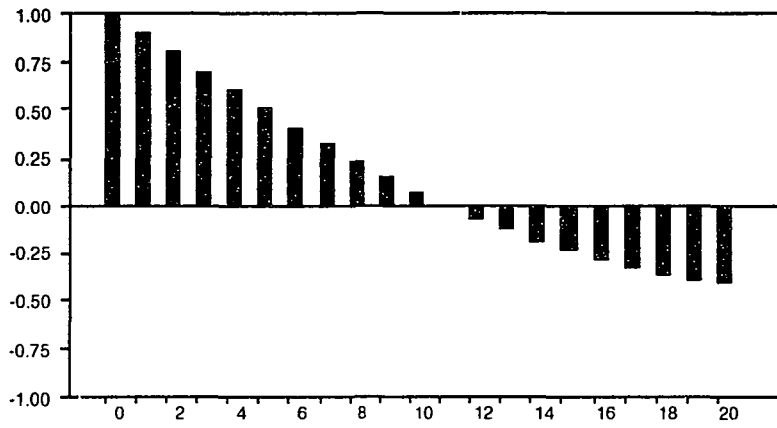


Figure 26. Correlogram of the logarithm of U.S. real GNP

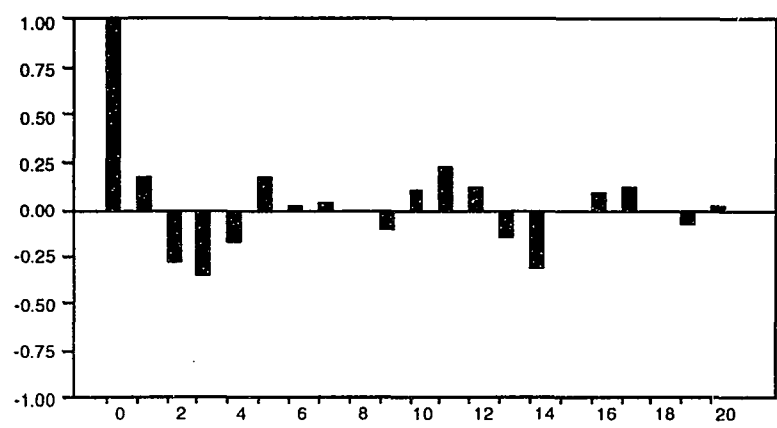


Figure 27. Correlogram of the first difference of the log of U.S. real GNP

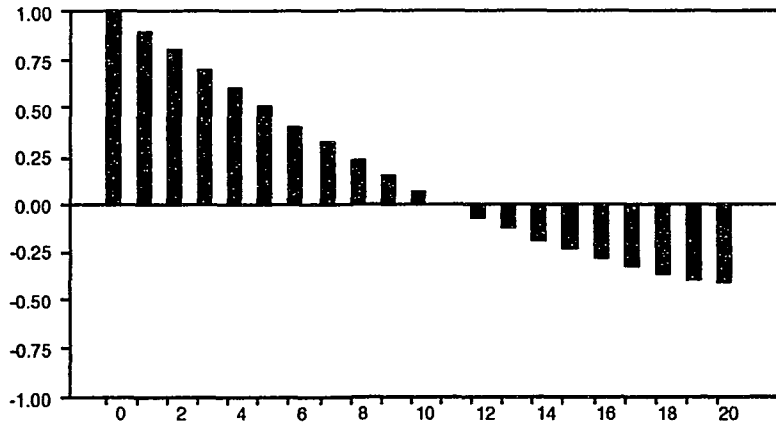


Figure 28. Correlogram of the logarithm of Taiwan's real GNP

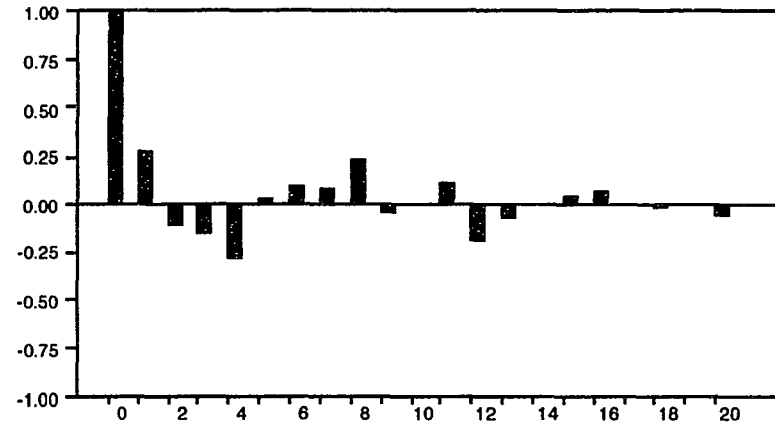


Figure 29. Correlogram of the first difference of the log of Taiwan's real GNP

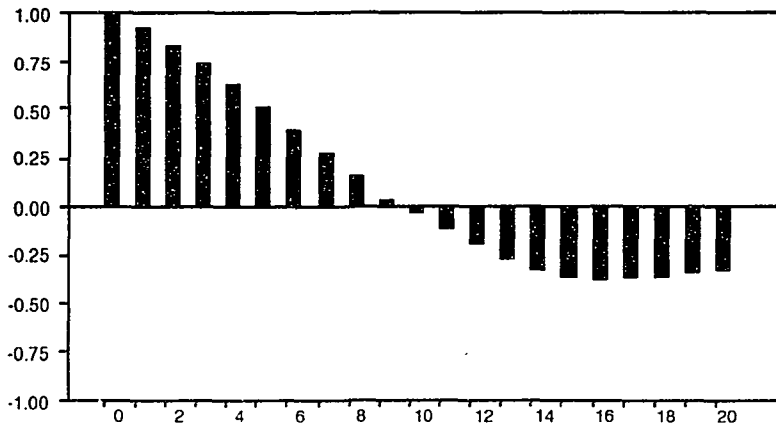


Figure 30. Correlogram of the logarithm of Taiwan's unit value of exports

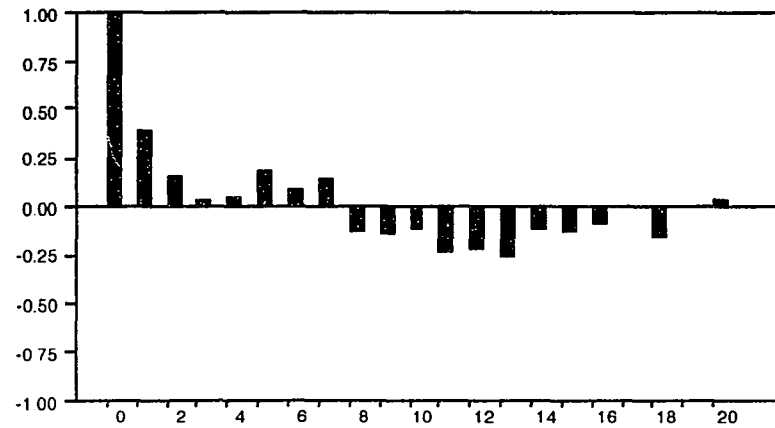


Figure 31. Correlogram of the first difference of the log of Taiwan's unit value of exports

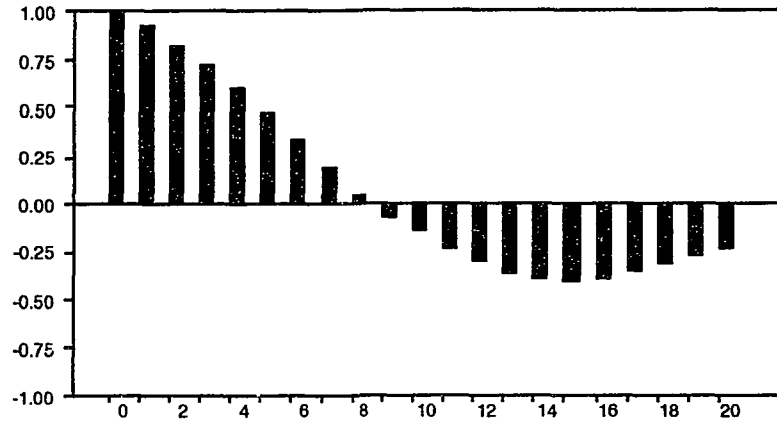


Figure 32. Correlogram of the logarithm of Taiwan's unit value of imports

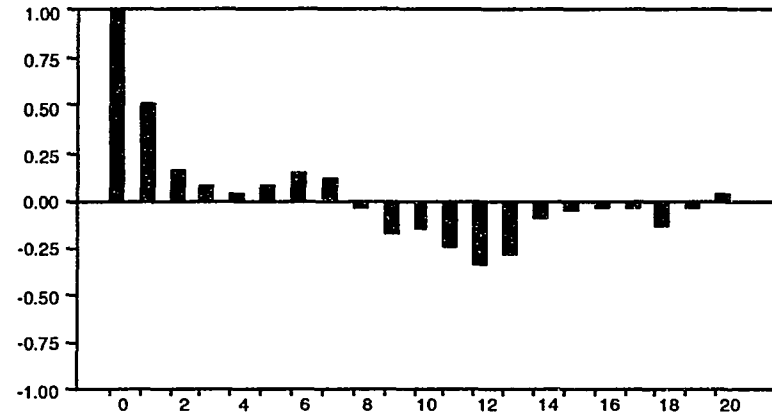


Figure 33. Correlogram of the first difference of the log of Taiwan's unit value of imports

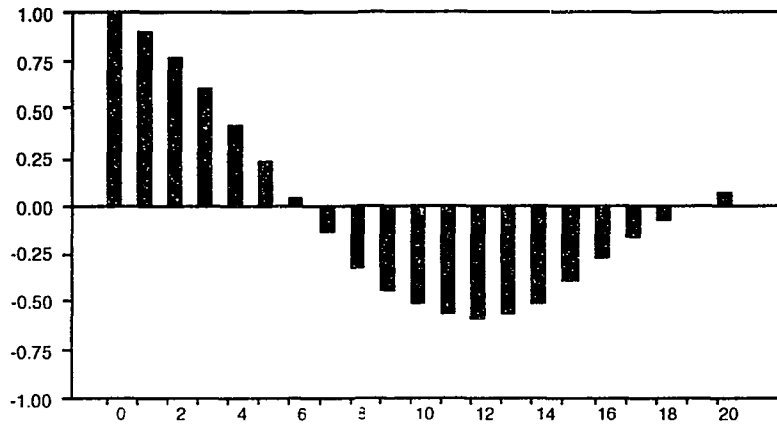


Figure 34. Correlogram of the logarithm of Taiwan's relative import price

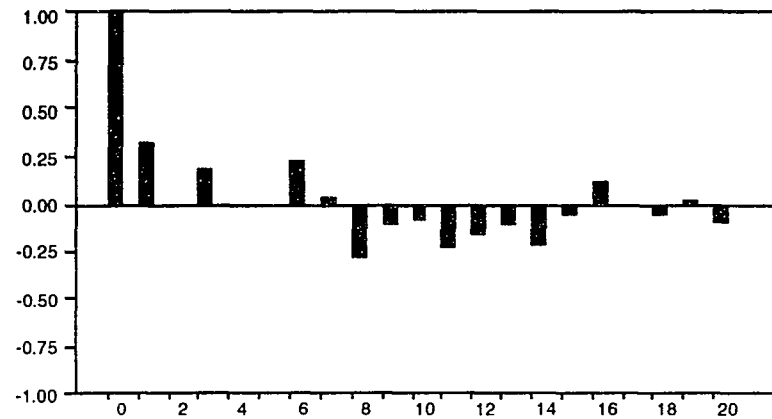


Figure 35. Correlogram of the first difference of the log of Taiwan's relative import price

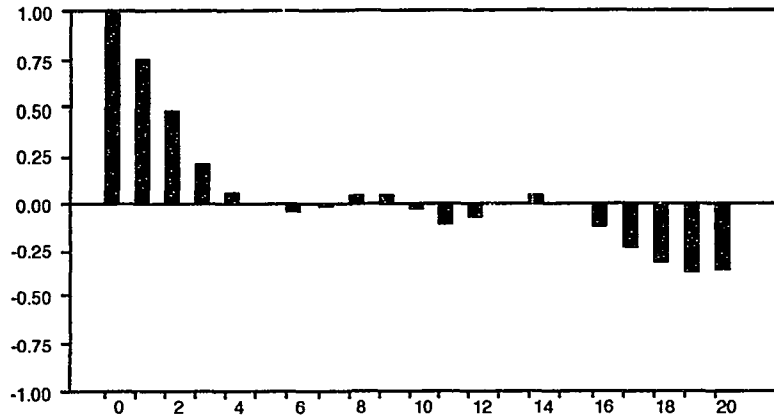


Figure 36. Correlogram of the logarithm of the real trade balance of Taiwan with the U.S.

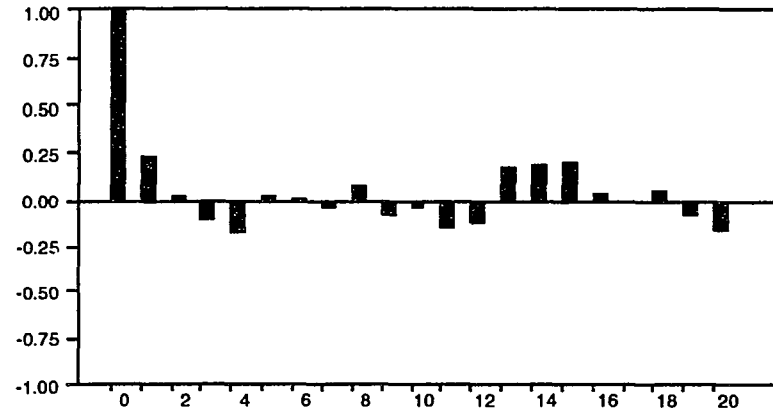


Figure 37. Correlogram of the first difference of the log of the real trade balance of Taiwan with the U.S.

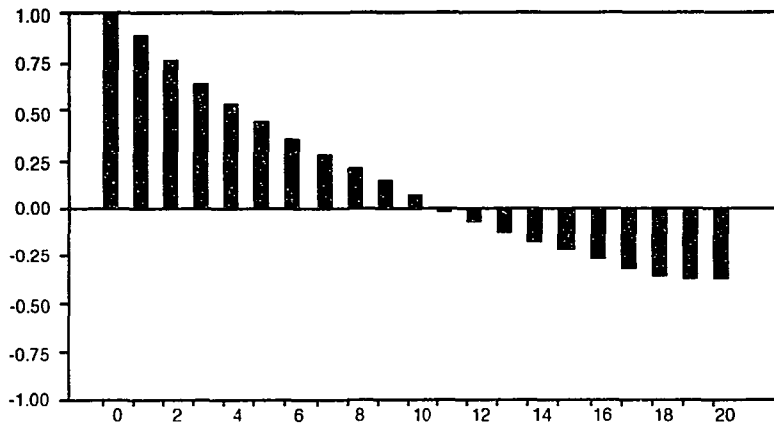


Figure 38. Correlogram of the logarithm of quantity of Taiwan exports to the U.S.

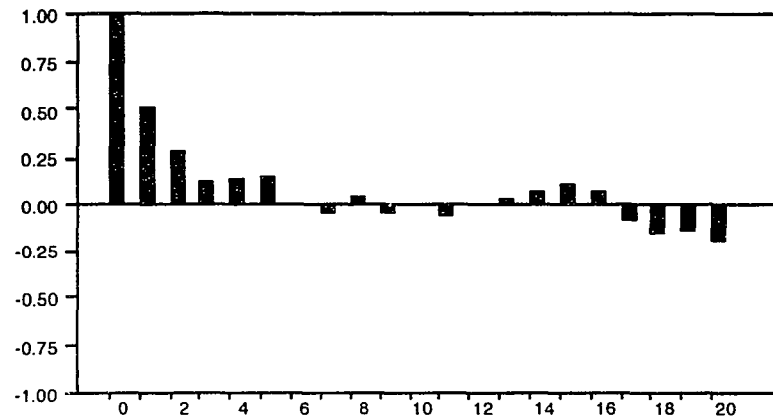


Figure 39. Correlogram of the first difference of the log of quantity of Taiwan exports to the U.S.

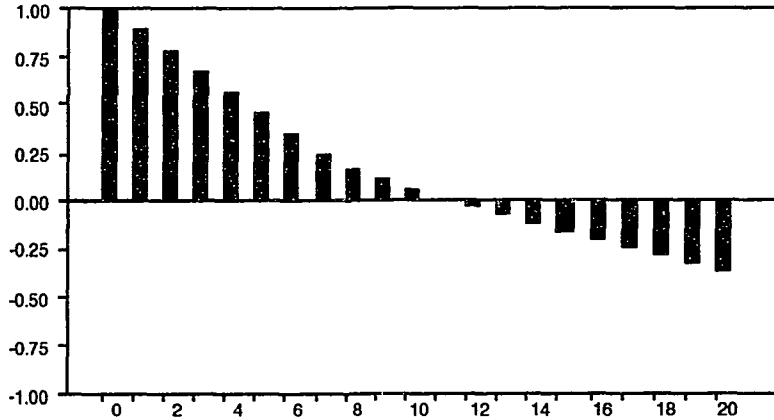


Figure 40. Correlogram of the logarithm of quantity of Taiwan imports from the U.S.

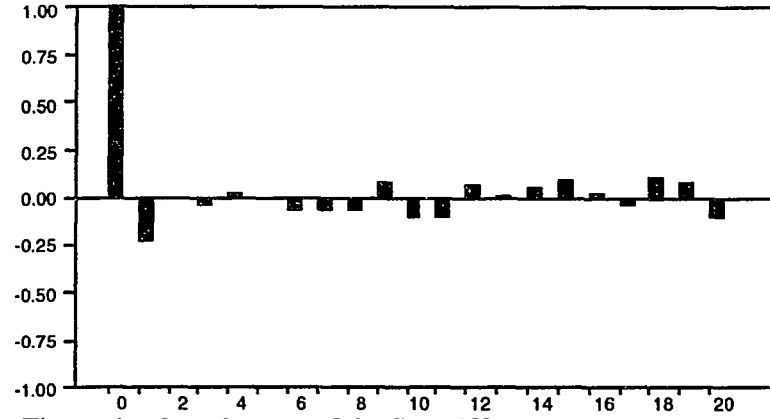


Figure 41. Correlogram of the first difference of the log of quantity of Taiwan imports from the U.S.

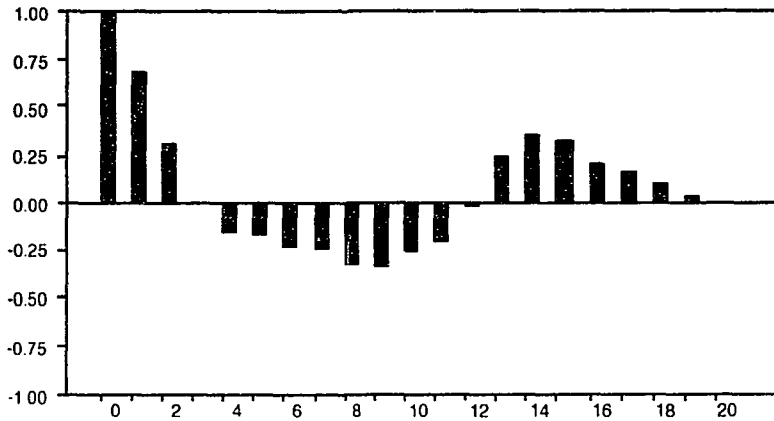


Figure 42. Correlogram of the logarithm of Taiwan-U.S. relative export price

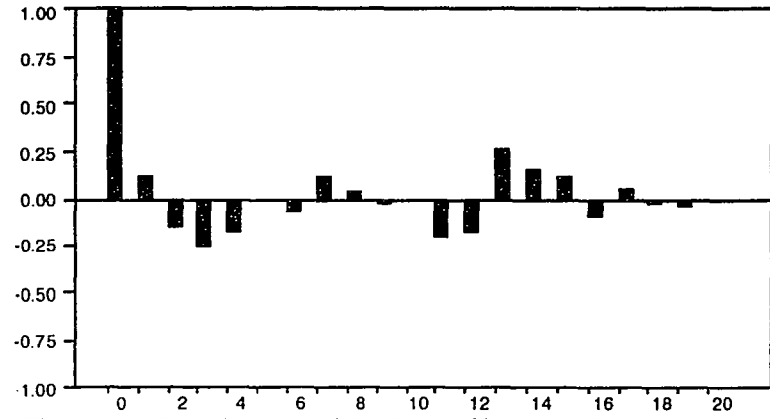


Figure 43. Correlogram of the first difference of the log of Taiwan-U.S. relative export price

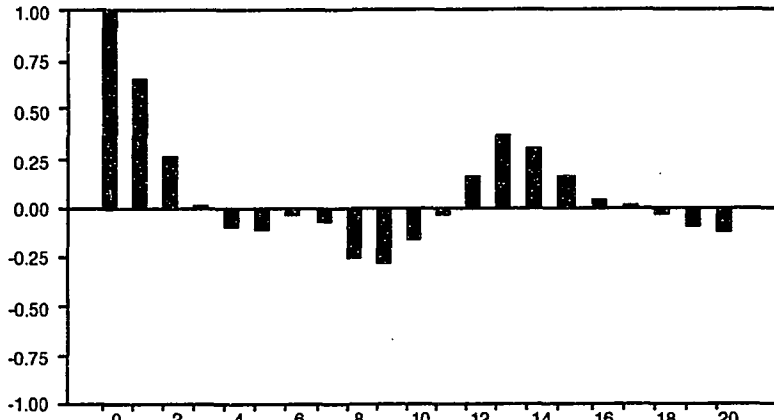


Figure 44. Correlogram of the logarithm of the real exchange rate of the New Taiwan dollar with respect to the U.S. dollar

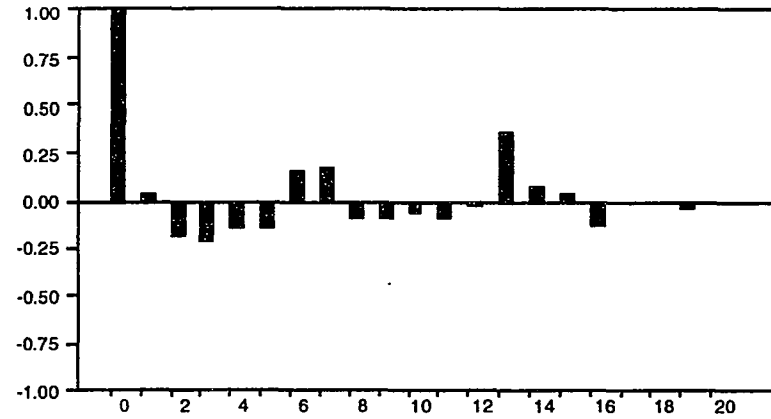


Figure 45. Correlogram of the first difference of the log of the real exchange rate of the New Taiwan dollar with respect to the U.S. dollar

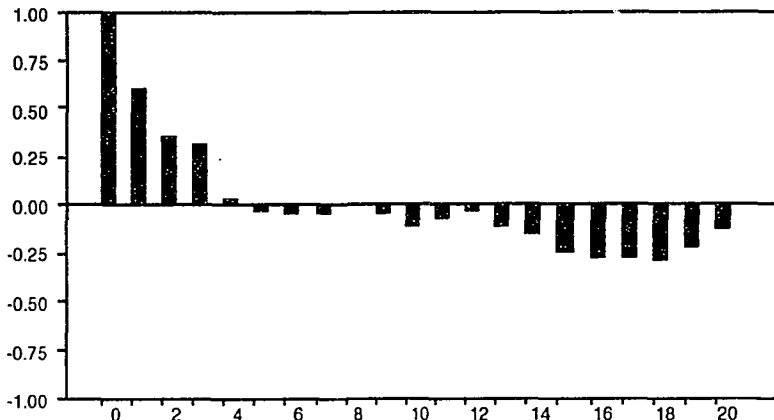


Figure 46. Correlogram of the logarithm of the real trade balance of Taiwan with Japan

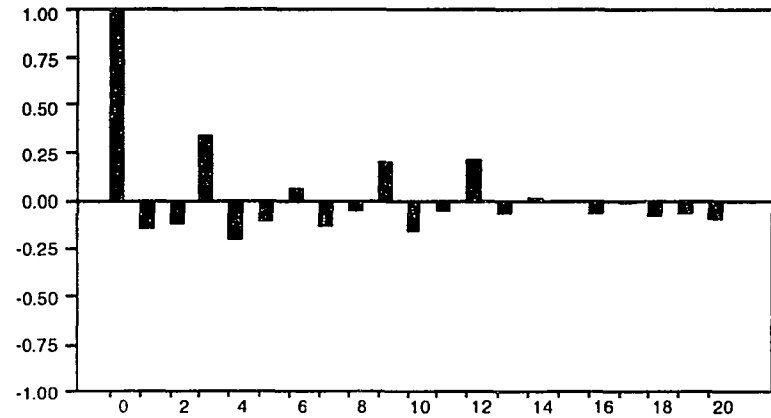


Figure 47. Correlogram of the first difference of the log of the real trade balance of Taiwan with Japan

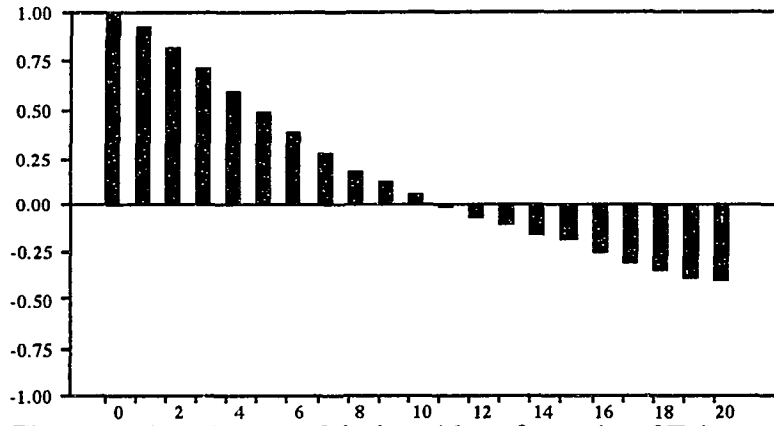


Figure 48. Correlogram of the logarithm of quantity of Taiwan exports to Japan

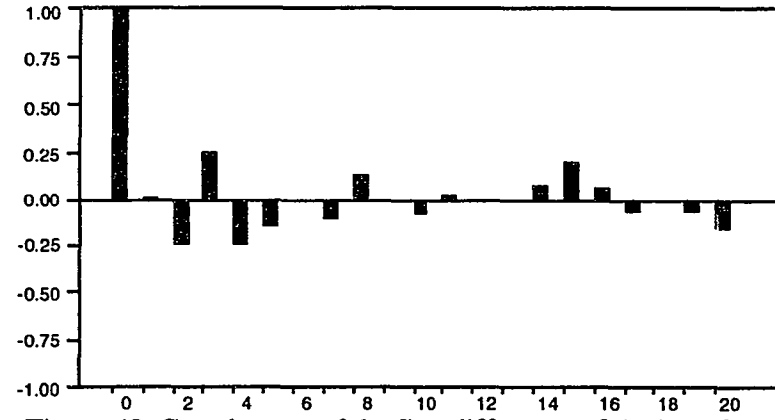


Figure 49. Correlogram of the first difference of the log of quantity of Taiwan exports to Japan

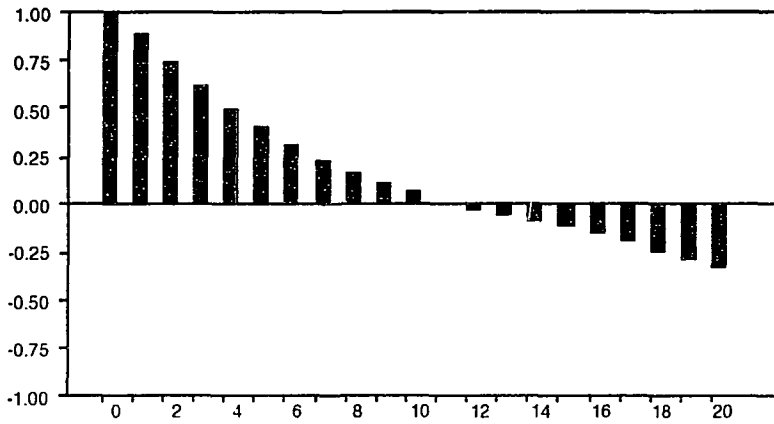


Figure 50. Correlogram of the logarithm of quantity of Taiwan imports from Japan

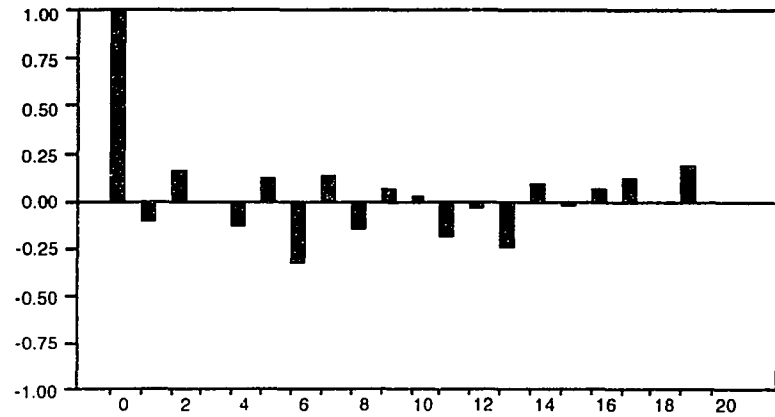


Figure 51. Correlogram of the first difference of the log of quantity of Taiwan imports from Japan

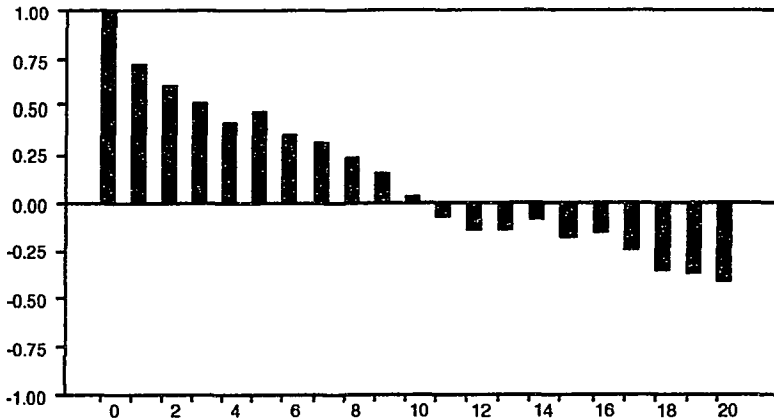


Figure 52. Correlogram of the logarithm of Taiwan-Japan relative export price

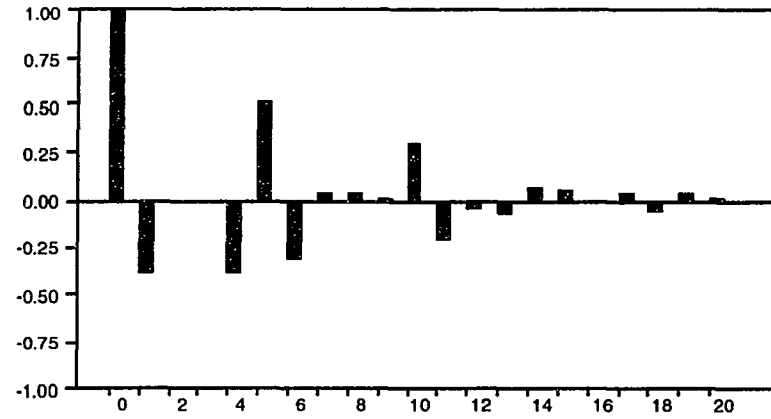


Figure 53. Correlogram of the first difference of the log of Taiwan-Japan relative export price

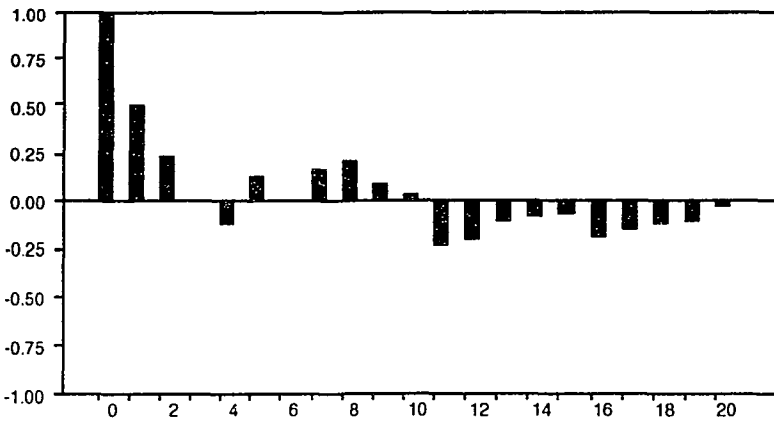


Figure 54. Correlogram of the logarithm of the real exchange rate of the New Taiwan dollar with respect to the Japanese yen

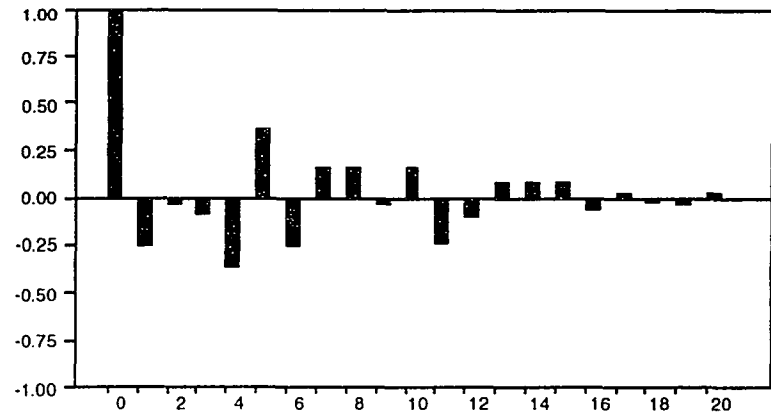


Figure 55. Correlogram of the first difference of the log of the real exchange rate of the New Taiwan dollar with respect to the Japanese yen

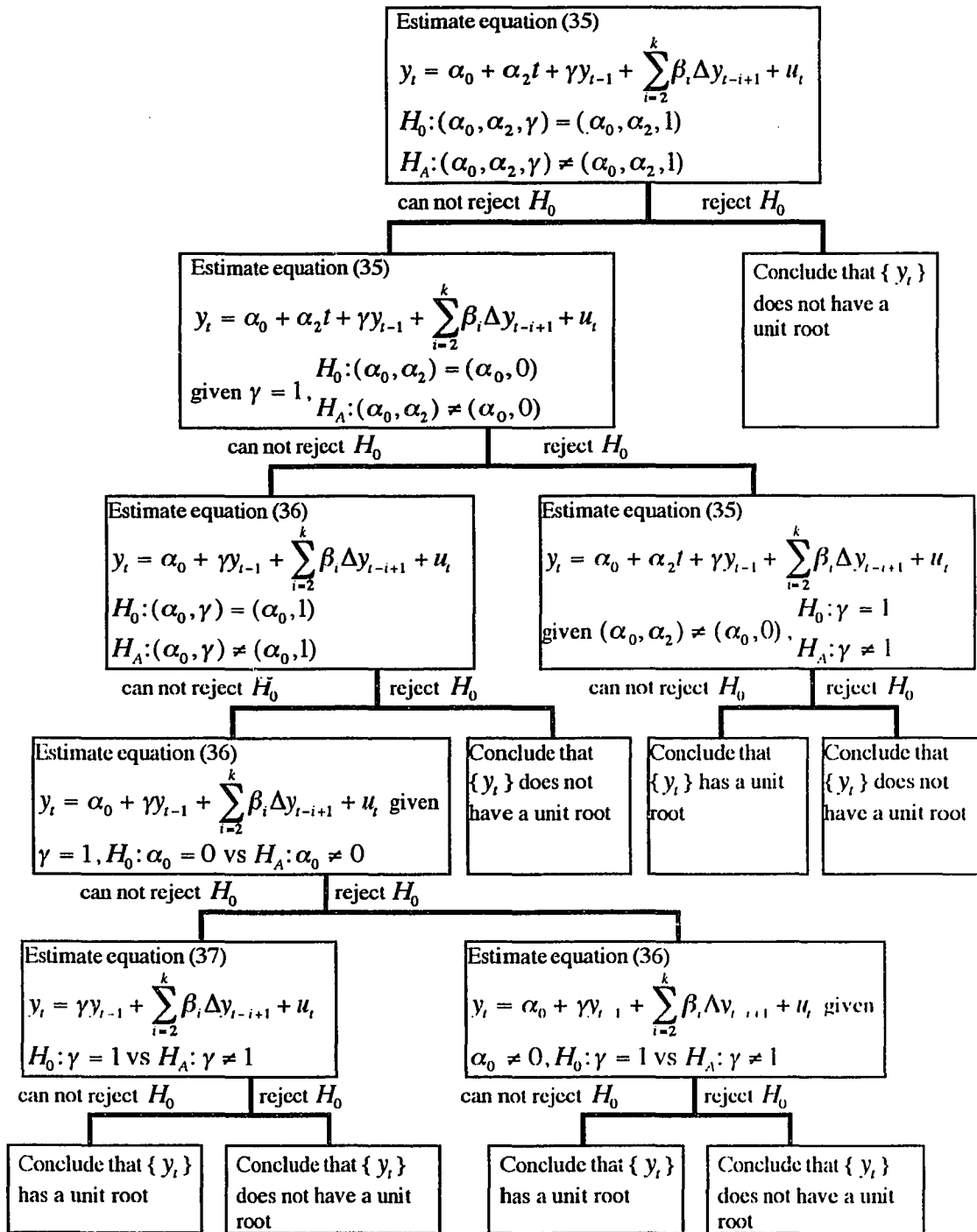


Figure 56. A sequential procedure of the augmented Dickey-Fuller test for unit root.

Source: Enders, 1995, Figure 4.7, p. 257.

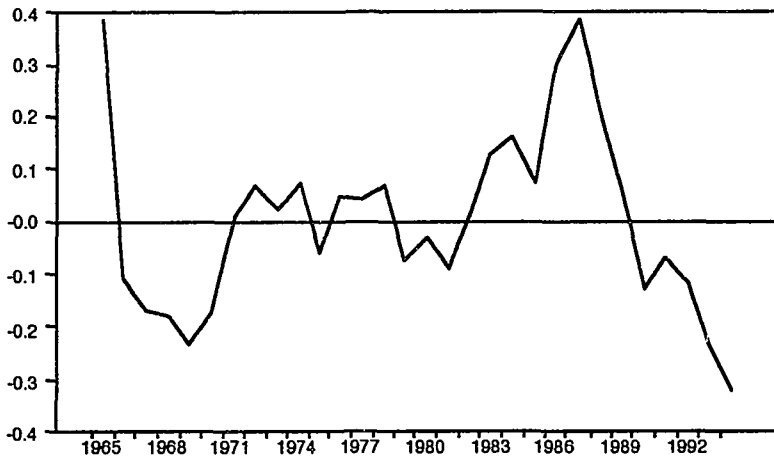


Figure 57. The residual of the cointegrating regression for U.S. demand for Taiwan exports

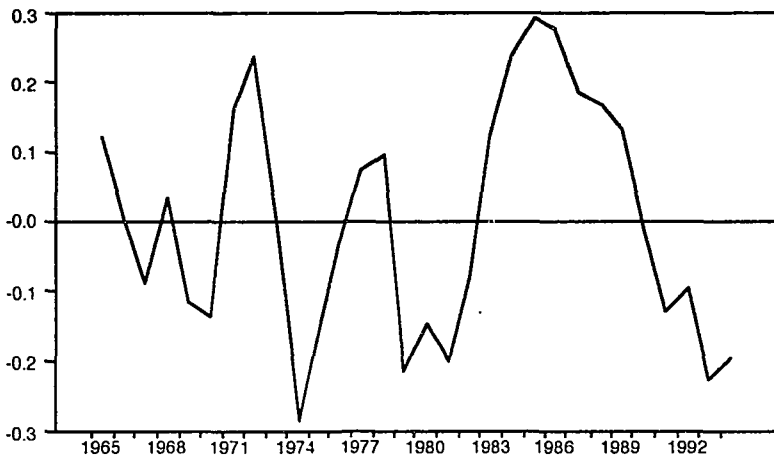


Figure 59. The residual of the cointegrating regression for Taiwan's export supply to the U.S.

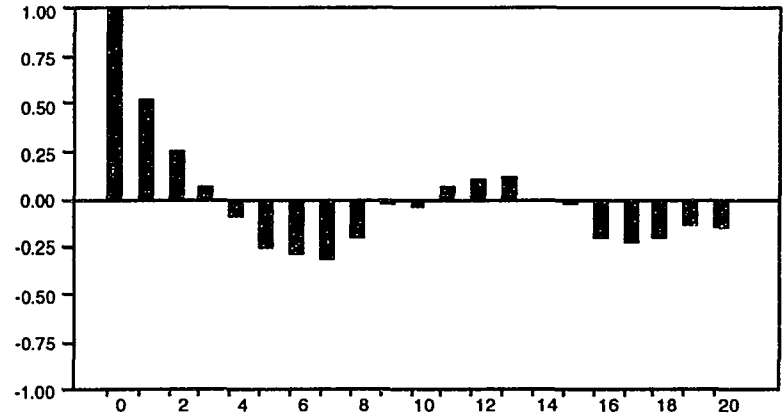


Figure 58. Correlogram of cointegration testing for U.S. demand for Taiwan exports

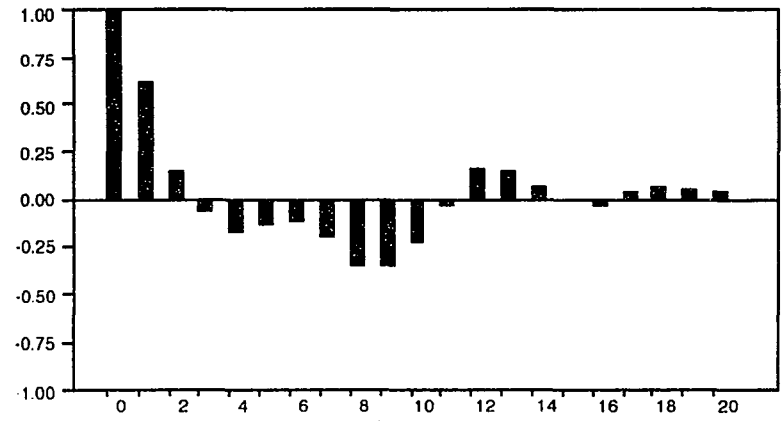


Figure 60. Correlogram of cointegration testing for Taiwan's export supply to the U.S.

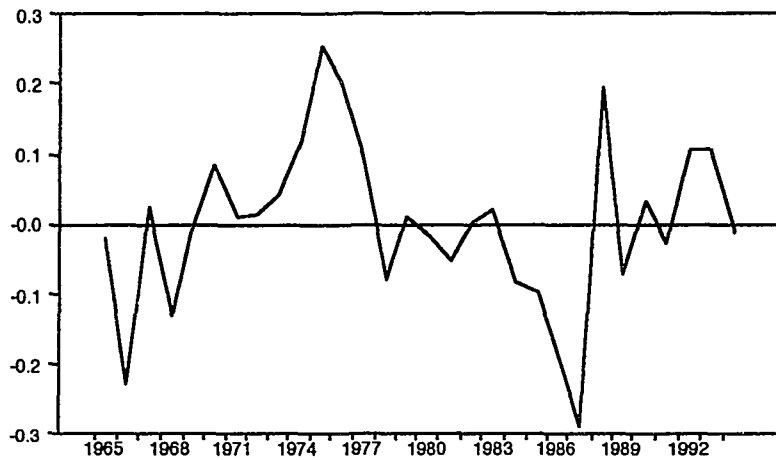


Figure 61. The residual of the cointegrating regression for Taiwan's import demand from the U.S.

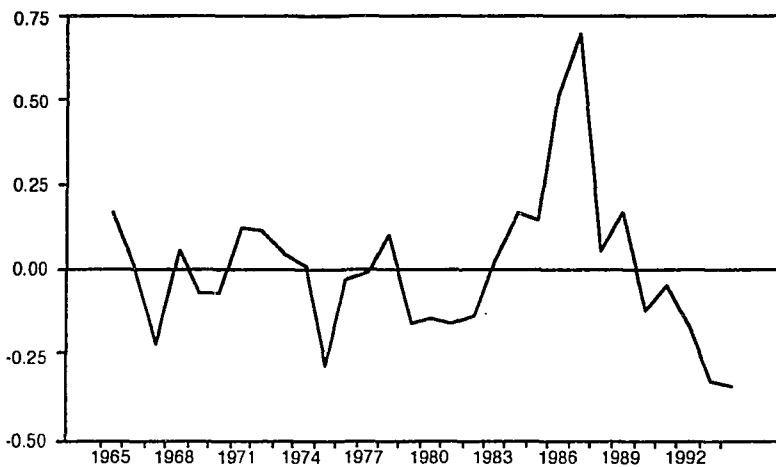


Figure 63. The residual of the cointegrating regression for Taiwan's trade balance with the U.S.

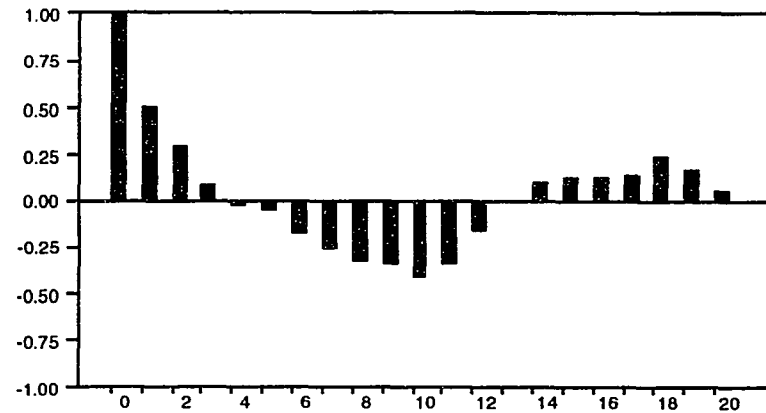


Figure 62. Correlogram of cointegration testing for Taiwan's import demand from the U.S.

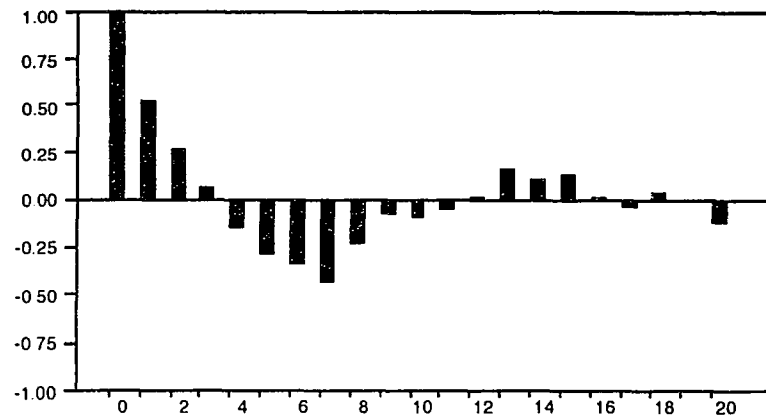


Figure 64. Correlogram of cointegration testing for Taiwan's trade balance with the U.S.

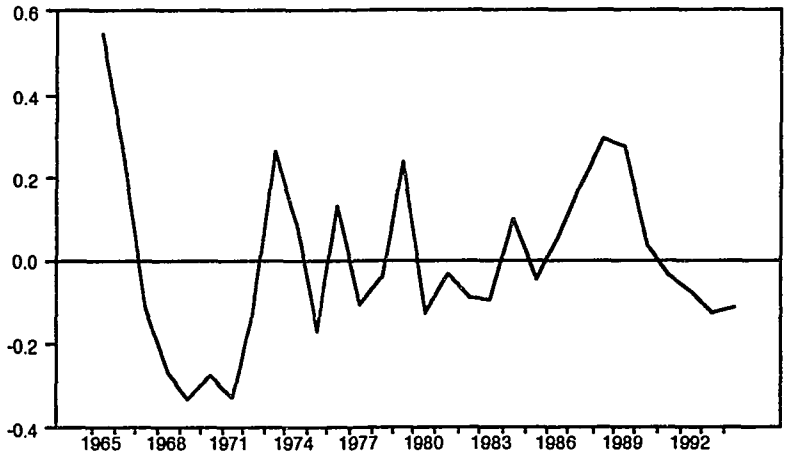


Figure 65. The residual of the cointegrating regression for Japan's demand for Taiwan exports

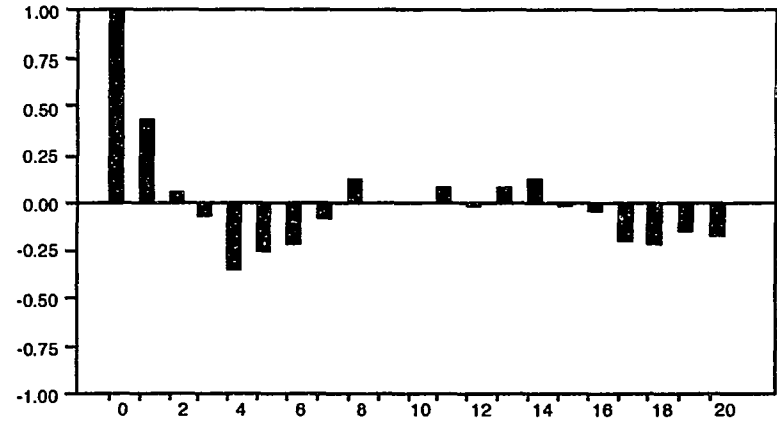


Figure 66. Correlogram of cointegration testing for Japan's demand for Taiwan exports

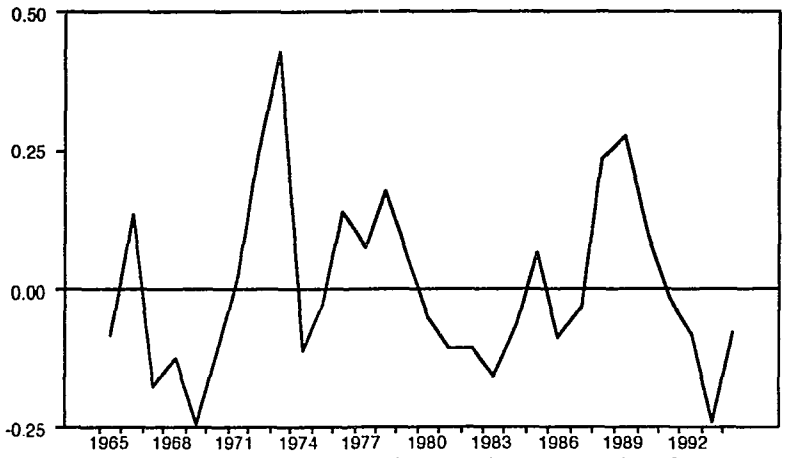


Figure 67. The residual of the cointegrating regression for Taiwan's export supply to Japan

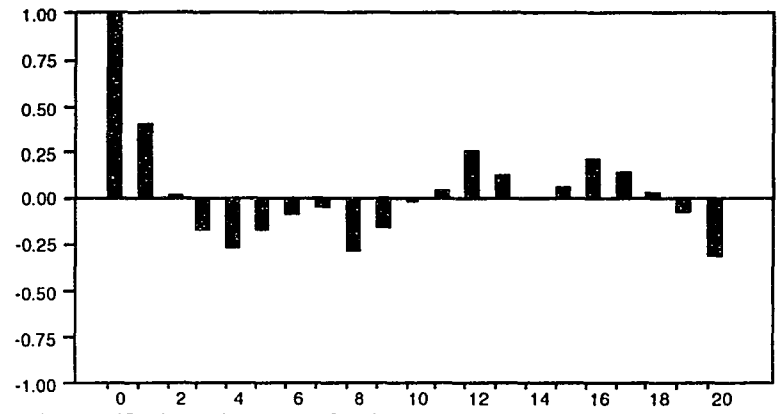


Figure 68. Correlogram of cointegration testing for Taiwan's export supply to Japan

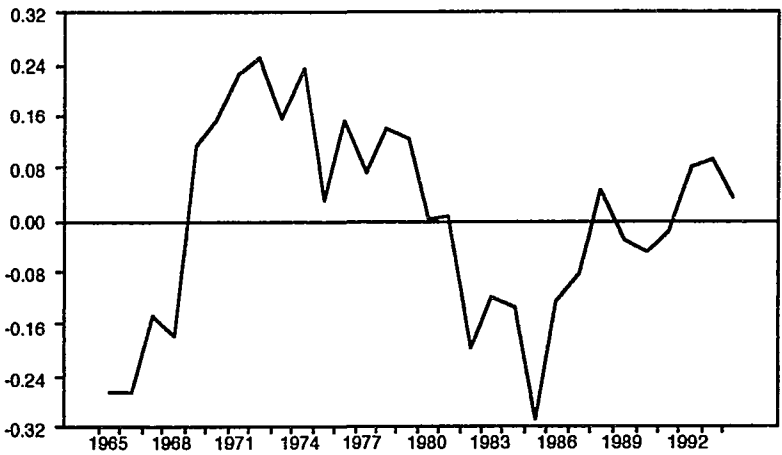


Figure 69. The residual of the cointegrating regression for Taiwan's import demand from Japan

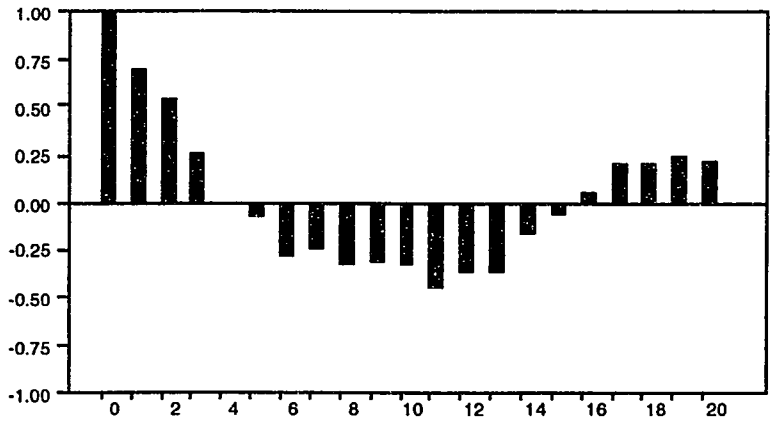


Figure 70. Correlogram of cointegration testing for Taiwan's import demand from Japan

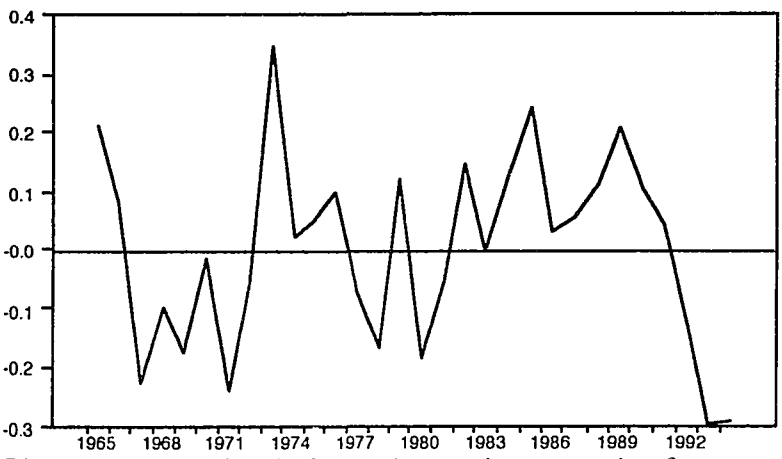


Figure 71. The residual of the cointegrating regression for Taiwan's trade balance with Japan

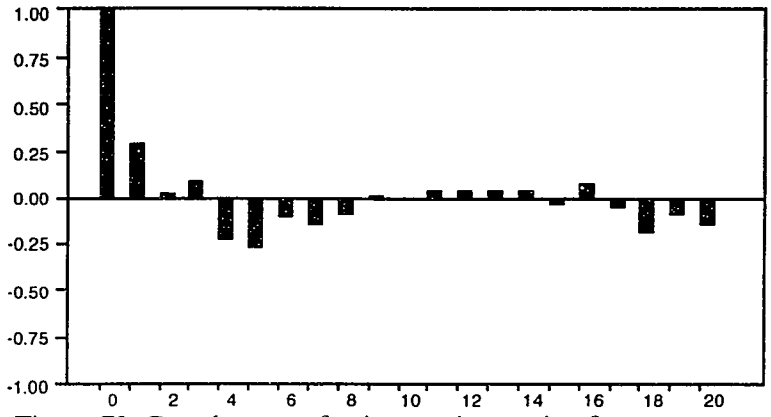


Figure 72. Correlogram of cointegration testing for Taiwan's trade balance with Japan

## APPENDIX C: DATA SOURCES AND VARIABLE DEFINITIONS

### Data Sources

All data are annual, for the period 1965-1994, and are taken from the various issues of following sources:

- (a) Taiwan statistical data book,
- (b) International Monetary Fund, International Financial Statistics,
- (c) Financial Statistics, Taiwan District, Republic of China.

Table C1 shows the source of each individual data series.

### Variable Definitions

All variables are expressed in logarithms.

The precise definitions of the variables used in this dissertation are:

The real exchange rate of New Taiwan dollar against U.S. dollar ( $LQ\_US$ ) is defined as the nominal exchange rate (units of New Taiwan dollar per U.S. dollar) multiplies the ratio of U.S. Producers Prices Index to Taiwanese Wholesale Prices Index. That is,  $LQ\_US = \ln\left(\frac{NTD \cdot PPI}{WPI}\right)$ . The real exchange rate of New Taiwan dollar against

Japanese yen ( $LQ\_J$ ) is defined as the nominal exchange rate (units of New Taiwan dollar per Japanese yen) multiplies the ratio of Japanese Wholesale Prices Index to Taiwanese Wholesale Prices Index. That is,  $LQ\_J = \ln\left(\frac{NTD}{YEND} \cdot \frac{JWPI}{TWPI}\right)$ .

The export quantity ( $LEX$ ) is defined as the value of merchandise exports deflated by the unit value of exports. ( $LEX = \ln\left(\frac{NTD \cdot EX}{UVEX}\right)$ )

The import quantity ( $LIM$ ) is defined as the value of merchandise imports deflated by the unit value of imports. ( $LIM = \ln\left(\frac{NTD \cdot IM}{UVIM}\right)$ )

The real trade balances (LB) are defined as the ratios of exports to imports.

$$(LB = \ln(\frac{EX}{IM}))$$

The real income of Taiwan (LTWGNP) is defined as Taiwan's real GNP, 1986 prices. ( $LTWGNP = \ln(TWGNP)$ )

The real income of Japan (LJGNP) is defined as Japanese real GNP, 1985 prices. ( $LJGNP = \ln(JGNP)$ )

The real income of the U.S. (LUSGNP) is defined as U.S. real GNP, 1985 prices. ( $LUSGNP = \ln(USGNP)$ )

The relative export price (LPX) is defined as the unit value of exports divided by foreign price. ( $LPX = \ln(\frac{UVEX}{NTD \cdot PPI})$ )

The relative import price (LPM) is defined as the unit value of imports divided by domestic price. ( $LPM = \ln(\frac{UVIM}{WPI})$ )

Table 20  
Data sources

Data	Symbol	Source	Location
Unit value of exports	UVEX	(b) and (c)	line 74
Unit value of imports	UVIM	(b) and (c)	line 75
Merchandise Exports	EX	(a)	Commodity with major trading partners
Merchandise Imports	IM	(a)	Commodity with major trading partners
U.S. Producers Prices Index	PPI	(b)	line 63
Japanese Wholesale Prices Index	JWPI	(b)	line 63
Taiwan's Wholesale Prices Index	TWPI	(a)	Price indices
Exchange rate (NT\$/)	NTD	(b) and (c)	line ae
Exchange rate (¥/\$)	YEND	(b)	line ae
Taiwan's real GNP	TWGNP	(a)	Gross domestic product and gross national product
Japanese real GNP	JGNP	(b)	line 99 a.r
U.S. real GNP	USGNP	(b)	line 99 a.r

Note: (a) represents Taiwan statistical data book, (b) represents International Monetary Fund, International Financial Statistics, and (c) represents Financial Statistics, Taiwan District, Republic of China.

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