

**The Trade Imbalance between the United States and China:  
The Role of Exchange Rate and Trade Liberalization**

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## **Abstract**

The pattern of trade between the United States and China has dramatically changed during the past 15 years. Until 1992, the commodity trade volume between the two countries was around \$10 billion per year, but it grew to \$60 billion in 1999. Because China has kept its currency (yuan or renminbi) pegged to the U.S. dollar since 1994, its current large trade surplus with the United States has led some critics to claim that the yuan is undervalued.

The aim of this paper is to examine the effect of the U.S.-China bilateral exchange rate on the pattern of trade between the two countries after controlling for alternative factors influencing U.S.-Chinese bilateral trade flows.

The results suggested that the U.S-China bilateral exchange rate does not have an important role in explaining bilateral trade between the two countries, while the relative exchange rate between the United States and the South-East Asian countries are more important in explaining the trade imbalance between the United States and China.

## Highlights

The pattern of trade between the United States and China has dramatically changed during the past 15 years. Until 1992, the commodity trade volume between the two countries was around \$10 billion per year, but it grew to \$60 billion in 1999. More importantly, China's trade surplus with the United States has increased with the increased trade volume between the two countries. China had a trade deficit with the United States in 1987, but it became a surplus in the mid-1990s and grew to about \$100 billion in 2002. Because China has kept its currency (yuan or renminbi) pegged to the U.S. dollar since 1994, its current large trade surplus with the United States has led some critics to claim that the yuan is undervalued.

The aim of this paper is to examine the effect of the U.S.-China bilateral exchange rate on the pattern of trade between the two countries. To examine the issue empirically, however, it is important to construct a model controlling for alternative factors influencing U.S.-Chinese bilateral trade flows in order to avoid the potential bias due to omitted variables. In fact, two alternative factors are frequently referred to as affecting the pattern of trade in the relevant literature, namely, trade liberalization and the third country effect of exchange rate.

After controlling two alternative factors, we reach two important conclusions. First, the exchange rate (both bilateral and relative exchange rate) does not have an important role in explaining bilateral trade between the two countries except for High-tech manufacturing products. In the case of High-tech manufactured products, the relative exchange rate between the United States and the South-East Asian countries are more important in explaining the trade imbalance problem between the United States and China. Considering the fact that the U.S.-Chinese trade imbalance problem heavily depends on the dramatic increase in China's share of High-tech manufactures trade, the results of this study suggest that a real depreciation of the U.S. dollar compared to the currencies of the South-East Asian countries would be more helpful for solving the trade imbalance problem between the two countries.

Second, a less than one-to-one increase in China's trade share in response to increasing trade volume (or trade liberalization) is found in the case of relatively homogenous products, such as agricultural goods, while a more than one-to-one increase in China's trade share in response to increasing trade volume is found in the most of manufactured products, especially sophisticated manufactured products. In fact, these results support the view that trade integration with China would lead to a loss of jobs in the United States. However, as Gabriel (2003) notes, consumers in the United States also gain due to the cheaper manufacturing goods imported from China. Finally, the U.S. agricultural sector is expected to gain more from the process of trade liberalization than China does.

# **The Trade Imbalance between the United States and China: The Role of Exchange Rate and Trade Liberalization**

**Guedae Cho and Won W. Koo\***

## **INTRODUCTION**

The pattern of trade between the United States and China has dramatically changed during the past 15 years. Until 1992, the commodity trade volume between the two countries was around \$10 billion per year, but it grew to \$60 billion in 1999. More importantly, China's trade surplus with the United States has increased with the increased trade volume between the two countries. China had a trade deficit with the United States in 1987, but it became a surplus in the mid-1990s and grew to about \$100 billion in 2002. Because China has kept its currency (yuan or renminbi) pegged to the U.S. dollar since 1994, its current large trade surplus with the United States has led some critics to claim that the yuan is undervalued. For instance, Goldstein (2003) argues that the under-valuation of the yuan is on the order of 15 to 20 percent in 2002. However, this opinion is countered by the fact that China's overall trade surplus has not been as large (around \$30 billion at the end of 2002). Hence, others believe that the trade imbalance problem between the two countries is simply due to relatively lower unit costs in China compared to the United States. While the question of whether the bilateral exchange rate has played an important role in explaining the trade imbalance problem between the two countries is highly controversial, there have not been many empirical studies examining this issue.

The aim of this paper is to examine the effect of the U.S.-China bilateral exchange rate on the pattern of trade between the two countries. To examine the issue empirically, however, it is important to construct a model controlling for alternative factors influencing U.S.-Chinese bilateral trade flows in order to avoid the potential bias due to omitted variables. In fact, two alternative factors are frequently referred to as affecting the pattern of trade in the relevant literature.

The first factor is related to an increasing trend in the volume of U.S.-Chinese bilateral trade (or a reduction of trade barriers) since the mid-1990s. In fact, there is no theoretical reason for believing that trade liberalization causes a proportionate increase in bilateral exports. Under the increasing returns to scale (IRS) model of Krugman (1980), a reduction in trade barriers will result in substantial changes in the pattern of intra-industry trade until there is a perfect specialization. The model also suggests the possibility that the larger country enjoys more than a one-to-one increase in exports, known as the 'home market effect of trade liberalization.' On the other hand, under the national product differentiated (NPD) model, goods such as agricultural products are distinguished by nationality (Armington 1969). For these types of goods, intra-industry trade can occur not because of economies of scale but because they are imperfectly

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substitutable. In addition, Head and Ries (2001) show that, for these types of goods, a smaller country gains more from the trade liberalization. Therefore, according to these theories, it is a natural process that countries experience some degree of trade imbalance with trade liberalization during the transition period, although there are debates over which country and industry gains most.

The second factor is the impact of relative exchange rate movements. As Cushman (1986) has indicated, even if the exchange rate between two particular countries is stable, it does not necessarily mean that the exchange rate does not affect trade flows between these two countries. If one country's currency appreciates (or depreciates) relative to all other trading partners, trade flows between the two specific countries, with a stable exchange rate, can be affected by the third country effects. During the South-East Asian currency crisis of 1997-98, several countries (e.g., Thailand, Malaysia, the Philippines, Indonesia, and Korea) experienced deep depreciations of their currencies of 50 percent or more against the U.S. dollar. However, China did not devalue its currency and kept it fixed to the U.S. dollar despite a loss of competitiveness against its neighbors. On the other hand, during the period 1995-2000, the U.S. dollar experienced a 25 percent appreciation in real terms. Because the U.S. dollar and Chinese yuan have moved together since 1994, an appreciation of the U.S. dollar means a real appreciation of the Chinese currency compared to the currencies of South-East Asian countries. The strong yuan means that China has had more purchasing power in international commodity markets. China can import more from South-East Asian countries rather than from the United States because their products are relatively cheap. Therefore, there is a possibility that trade flows between the United States and China depend on relative exchange rate movements between the United States and other Asian countries rather than the movement of the U.S.-China bilateral exchange rate.

To examine this issue empirically, developing a structural model is desirable. However, we find that a serious data limitation prevents this possibility. For instance, a short span of trade data between the two countries does not provide enough observations for an empirical study. In order to overcome the data limitation, we categorize bilateral trade flows in three different industry groups using the International Standard Industrial Classification (ISIC) four-digit codes, which gives us enough observations for an empirical study. Using parsimonious reduced form equations, we reach two important conclusions. First, it is found that the U.S.-China bilateral exchange rate does not have an important role in explaining changes in bilateral trade flows in relatively homogenous and middle-tech manufactured products, while there is weak evidence that it has had some role in the case of trade of high-tech manufactured products. On the other hand, there is strong evidence that relative exchange rates between the United States and South-East Asian countries are relevant to changes in trade pattern between the United States and China in the case of high-tech manufactured products. Second, there is a less than a one-to-one increase in China's trade share in response to increasing trade volume in the case of the relatively homogenous products, including agricultural goods. On the other hand, we found more than a one-to-one increase in China's trade share in the case of manufactured products, especially high-tech manufactures, indicating that part of the U.S.-China trade imbalance problem is a natural process occurring during a transition period of trade liberalization.

The paper is organized as follows. In the second section, we sketch the broad dimensions of U.S.-Chinese bilateral trade and the exchange rate over the period 1987-1999. In section three, a brief discussion of the relevant economic theories predicting the relationship between trade liberalization and changes in trade flows will be presented. Section four explains two empirical models that are used in the empirical analysis. Data and econometric methods are presented in section five, followed by the study's empirical results in section six. The paper is summarized in the last section.

## **U.S.-CHINESE BILATERAL TRADE AND EXCHANGE RATE<sup>1</sup>**

### *U.S.-Chinese Bilateral Trade*

Although China lagged the United States in per capita income (\$908 in China and \$36,209 in the United States) in 2002, China has become the world's sixth-largest economy due to its large population. This demographic factor, coupled with an average annual GDP growth rate of more than 10 percent since 1980, strongly impacts the world economy. The country's trade performance reflects its growth dynamics. Exports plus imports were equal to more than 45 percent of China's GDP in 2002, compared to 15 percent in 1982. Before 1994, China showed no sustained trade surplus: the net current account balance alternated between positive and negative. Since 1995, we have observed a more persistent tendency toward a current-account surplus (McKinnon and Schnabl 2003).

Figure 1 illustrates the increasing and unequal bilateral trade volume between the United States and China. It is useful to focus on the rapid increase in trade volume since 1993. Until 1992, the bilateral trade volume between the countries was approximately \$10 billion; in 1999, it grew to around \$60 billion. More interestingly, China's trade surplus has increased with the growth in its trade volume with the United States.

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<sup>1</sup> Much of the summary in this section is based on the McKinnon and Schnabl (2003).

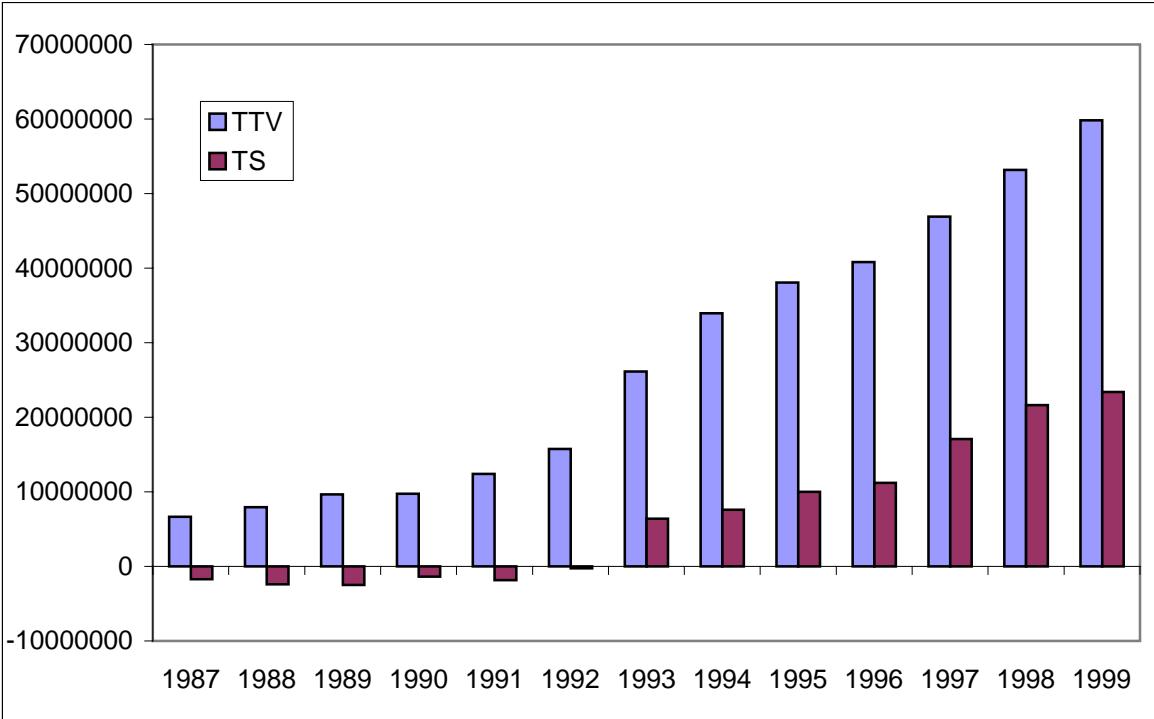


Figure 1. Total Bilateral Trade Volume (TTV) and Trade Surplus of China (TS) (Thousand U.S. dollar)

Comparisons between sectoral trade volumes and trade surpluses can generate some interesting information necessary for understanding changes in the overall pattern of bilateral trade between two countries during the period 1987-1999. To show this, we categorize industries into four different groups<sup>2</sup> by the ISIC 3 digit code: FBT, which includes the food, beverage, and tobacco industries; TALF, which includes the textile, wearing apparel, leather, and footwear industries; Mid-Tech manufactures, which includes most of the manufacturing industries using raw materials such as wood products, iron and steel, and rubber and plastic; and, finally, High-Tech manufactures, which includes most manufacturing industries producing relatively sophisticated products such as machinery, transportation equipment, and professional and scientific equipment.<sup>3</sup>

Figures 2 and 3 show changes in the bilateral trade volumes and China's trade surpluses in the case of the FBT and TALF groups over the period 1987-1999. For the FBT group, we can observe that, although bilateral trade volume has rapidly increased since 1993, China's trade has changed from surplus to deficit. In the case of the TALF group, the relationship is drastically different. In fact, China has an almost perfect comparative advantage in these labor-intensive products. Therefore, an increasing trade volume between the two countries results in increased exports from China to the United States, as we expected. The changes in the Middle-Tech and

<sup>2</sup> For a regression analysis, only three groups were examined because there is almost no intra-industry trade in the case of the TALF group.

<sup>3</sup> Details of the industries included in four different groups are presented in the Appendix.

High-Tech manufacturing groups are very important for understanding the change in the pattern of bilateral trade between the two countries under trade liberalization (Figures 4 and 5). It is clear that, with increased bilateral trade volumes in these sectors, China has changed its trade balance from deficit to surplus. Unlike the TALF group, China did not have a comparative advantage in these industries until 1994. However, it has enjoyed a comparative advantage since 1994 for many of the products in the Mid- and High-Tech manufacturing groups.

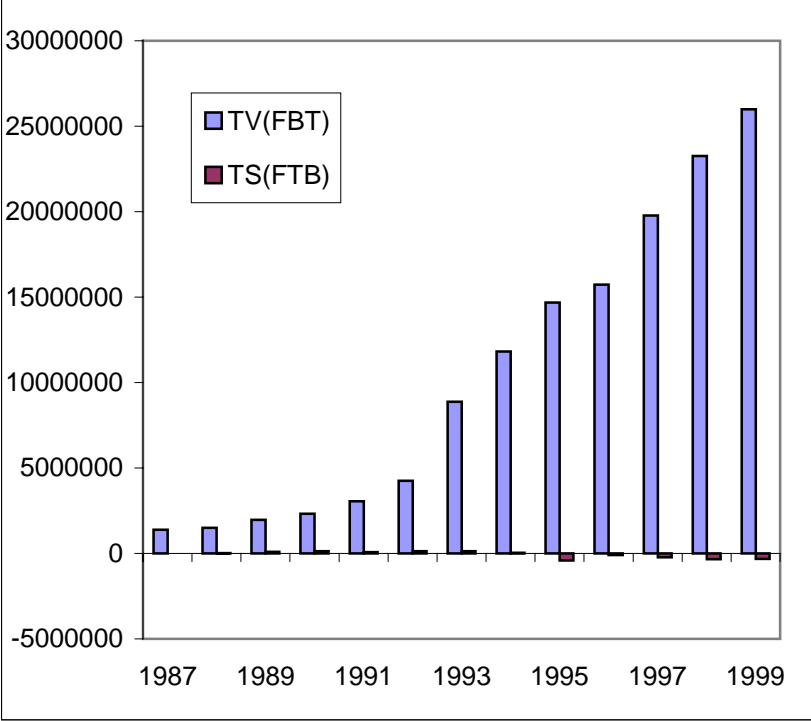


Figure 2. Total Trade and Surplus of China in FBT Group (Thousand U.S. dollar)

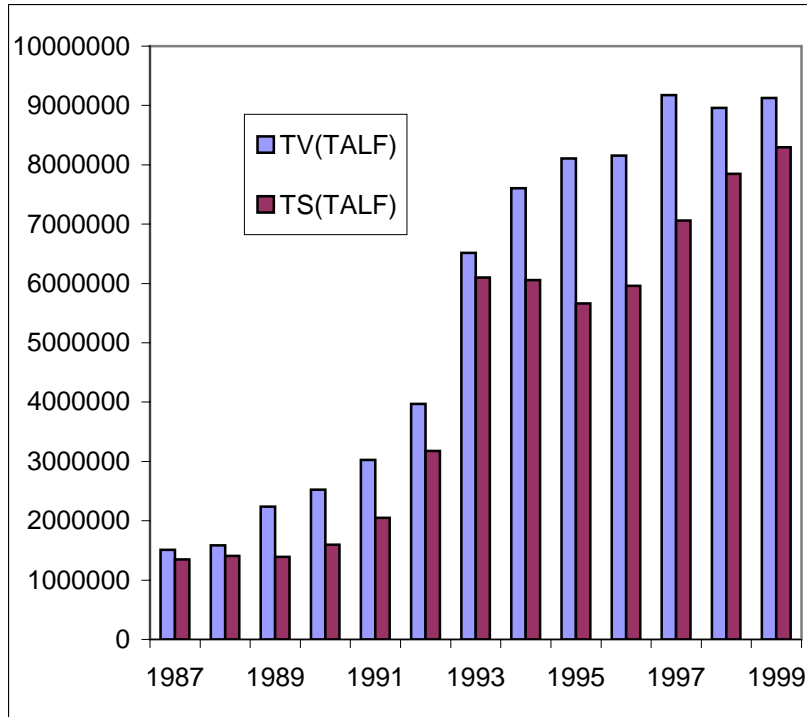


Figure 3. Total Trade and Surplus of China in TALF Group (Thousand U.S. dollar)

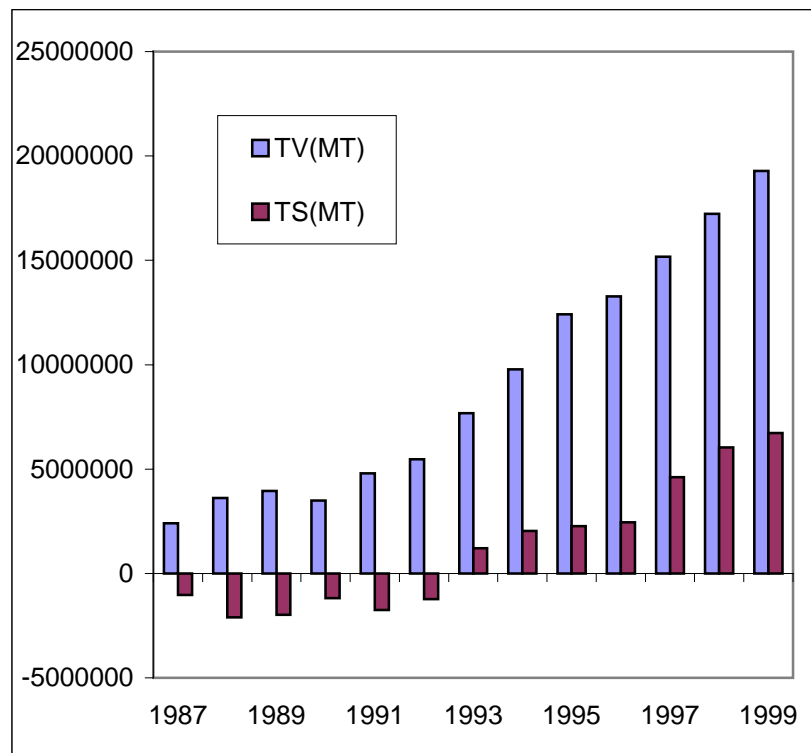


Figure 4. Total Trade and Surplus of China in Middle-Tech Group (Thousand U.S. dollar)

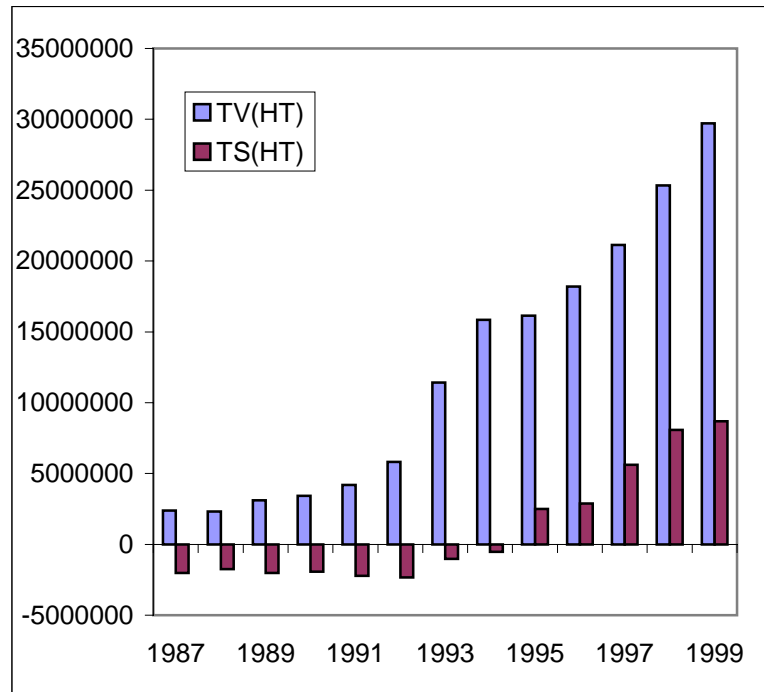


Figure 5. Total Trade and Surplus of China in High-Tech Group (Thousand U.S. dollar)

The remarkable transformation in the commodity composition of China's trade over the last two decades also gives us another interesting clue to understand the trade imbalance problem. In the 1980s, Chinese commodity trade exhibited the characteristics of a developing country. China's exports to the U.S. market were largely TALF and Mid-Tech manufacturing products. Figure 6 demonstrates that Chinese exports to the United States have shifted away from TALF products to High-Tech manufactures, while the share of Mid-Tech manufactures has remained almost constant. TALF products (58 percent) and Mid-Tech products (30 percent) accounted for more than 80 percent of Chinese exports to the United States in 1987, while FBT and High-Tech products were about 20 percent of total exports. In 1999, the composition of Chinese exports showed the characteristics of an industrialized economy. The relative weight of TALF fell to about 20 percent, while Mid-Tech products remained almost the same (31 percent). The percentage share of High-Tech products experienced a rapid increase, reaching more than a 45 percent share in total exports to the United States in 1999.

On the other hand, the commodity composition of Chinese imports from the United States does not show such a dramatic change. Figure 7 shows the variation of import share from each category. Although there has been some fluctuation during the period, no dramatic changes in import composition can be observed. What we learn from the commodity composition of China's exports to and imports from the United States is that most of the trade surplus during the recent period is due to a large increase in China's export share in High-Tech manufactures.

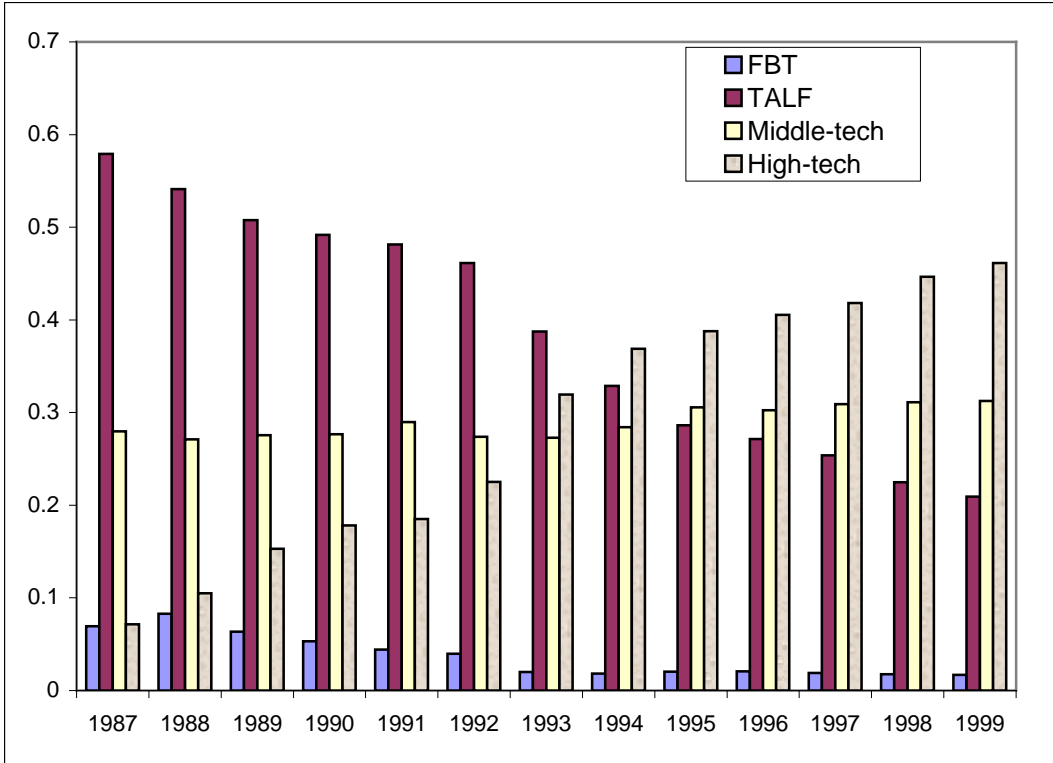


Figure 6. Sectoral Share of China's Exports to the United States

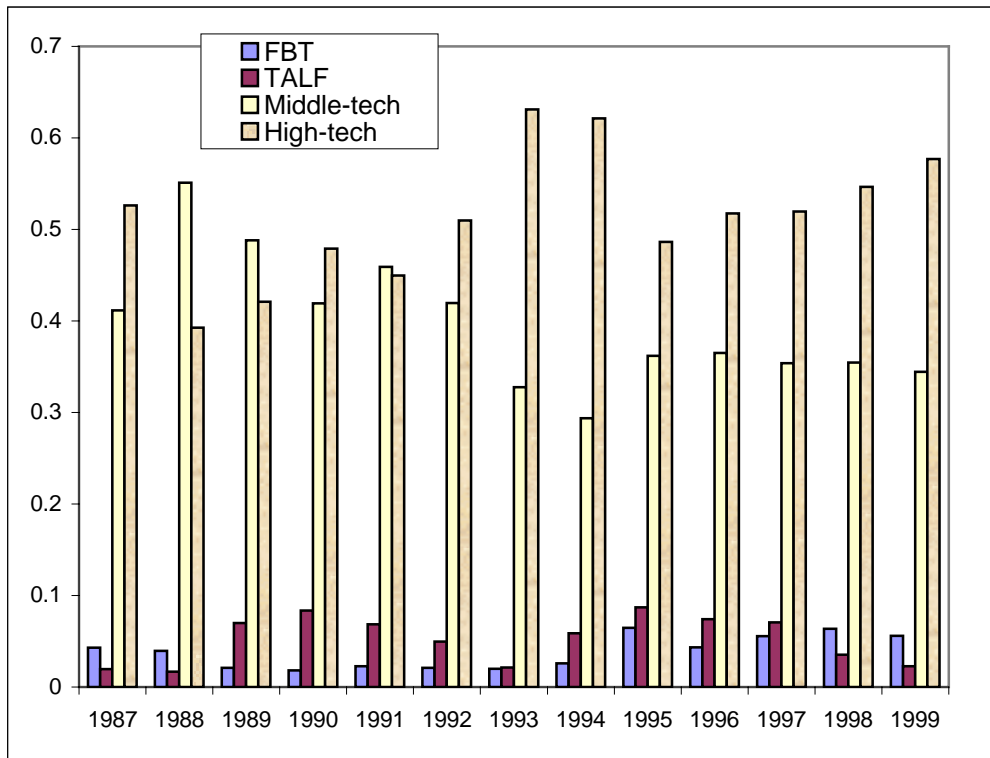


Figure 7. Sectoral Share of China's Imports from the United States

## Exchange Rates

A key aspect of the South-East Asian macro economy was the propensity of countries in the region (except Japan) to informally peg their currency to the U.S. dollar in non-crisis periods (McKinnon 2001). Since 1994, China has also kept the yuan stable at 8.3 yuan per U.S. dollar (Figure 8).<sup>4</sup> During the currency crisis of 1997-98, when the currencies of several South-East Asian countries, Indonesia, Korea, Malaysia, the Philippines, and Thailand, were unstable, these governments had to suspend their dollar pegs. This suspension was followed by deep overshooting depreciations of their currencies by 50 percent or more (Figures 9-13). Japan also experienced the depreciation of the yen by more than 30 percent from mid-1996 to mid-1998 (McKinnon and Schnabl 2003).

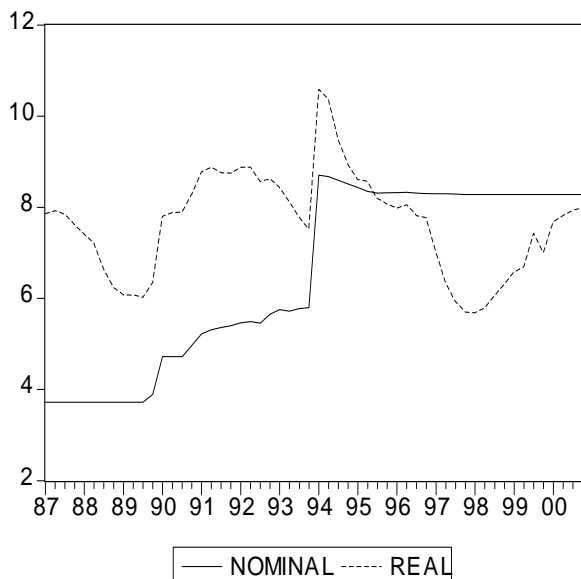


Figure 8. Nominal and Real Exchange Rates between the United States and China (the value of the U.S. dollar in terms of yuan)

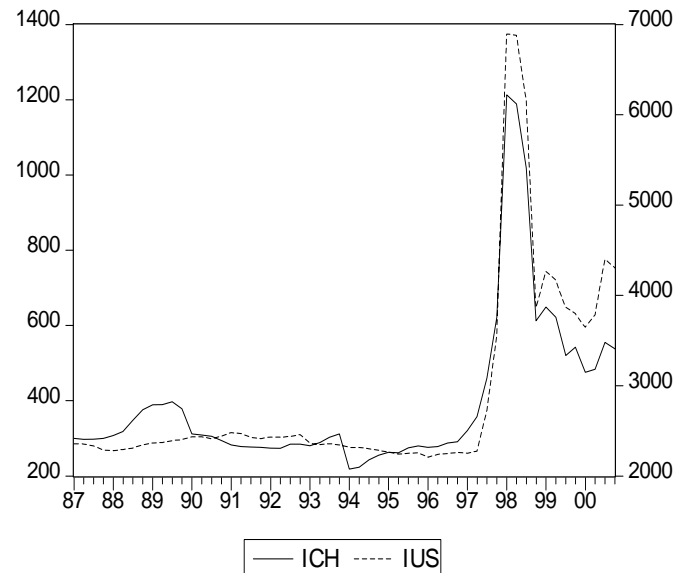


Figure 9. Real Exchange Rates of Indonesia with the United States (IUS) and with China (ICH)

<sup>4</sup> Although the nominal exchange rate between the United States and China has been fixed since 1994, their real exchange rate fluctuated. An interesting fact is the U.S. dollar had depreciated compared to Chinese currency over the period 1994-1998 in real terms.

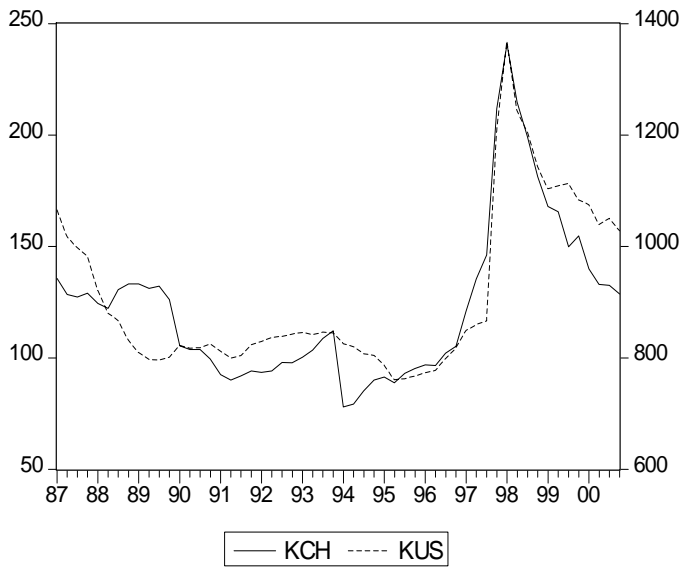


Figure 10. Real Exchanges Rates of Korea with the United States (KUS) and with China (KCH)

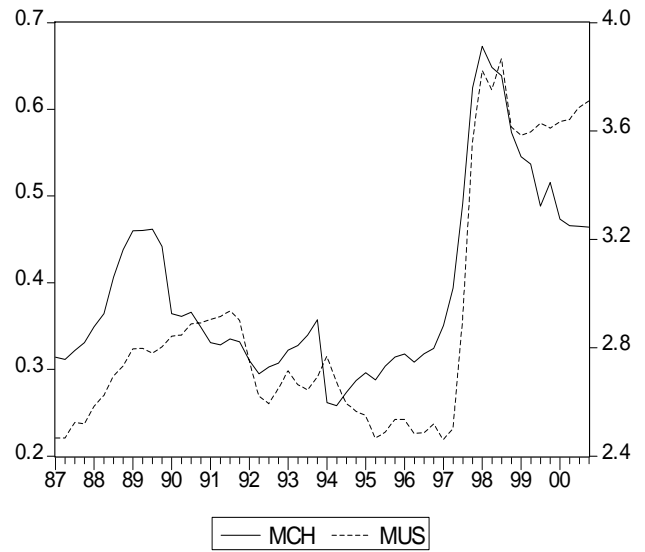


Figure 11: Real Exchange Rates of Malaysia with the United States (MUS) and with China (MCH)

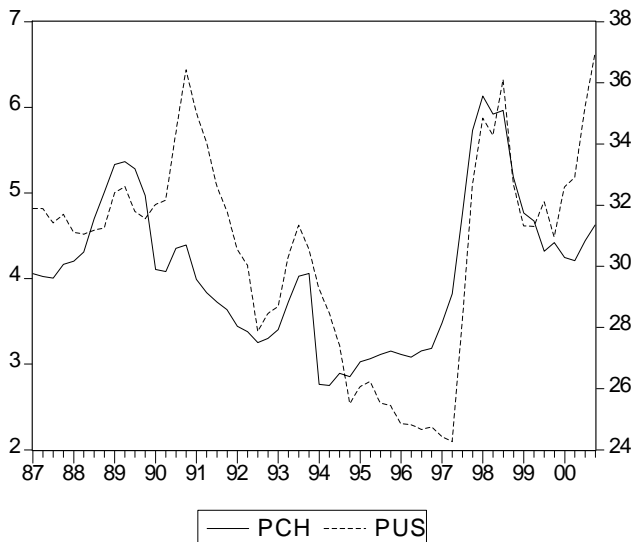


Figure 12. Real Exchange Rates of the Philippines with the United States (PUS) and with China (PCH)

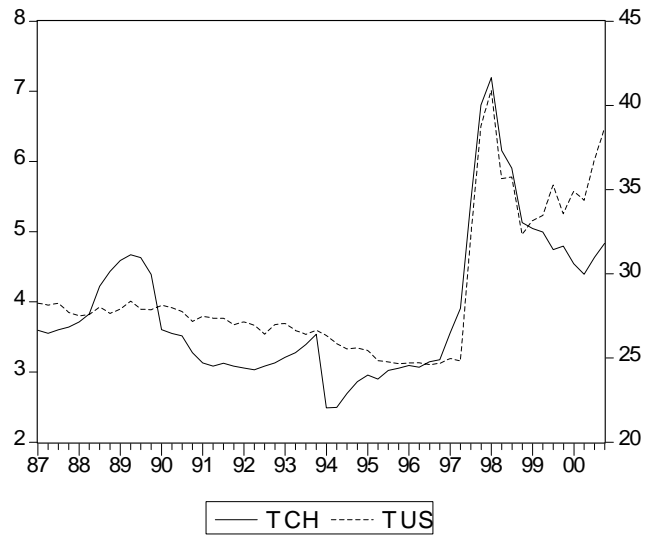


Figure 13: Real Exchange Rates of Thailand with the United States (TUS) and with China (TCH)

Although the cross-country spillover effects added pressure to China to devalue its currency, the country has kept its currency fixed and gained a great deal of credibility with foreign investors as a result. Because the U.S. dollar and Chinese yuan have moved together, an appreciation of the U.S. dollar has resulted in an appreciation of Chinese currency compared to the currencies of other Asian countries. The strong yuan gives China more purchasing power in international commodity markets. Therefore, it is natural that this exchange movement effectively triggers

Chinese imports from and hampers exports to other Asian countries. As indicated by McKinnon and Schnabl (2003), most of the Chinese imports from South-East Asian countries are intermediate (raw materials) goods used to produce high-tech manufacturing products, which is expected to be exported to the United States. Thus, there is a strong possibility that changes in the trade pattern of high-tech manufacturing products between the United States and China depend on relative exchange rate movements between the United States and Asian countries rather than movements in the U.S.-Chinese bilateral exchange rate.

## **INTRA-INDUSTRY TRADE AND TRADE LIBERALIZATION**

The data investigation in the previous section provides two important empirical facts. First, the most important factor causing a trade imbalance between the two countries has been due to the rapid increase in export share of high-tech manufacturing products from China. Second, the sectors in which China has traditionally had a comparative advantage (e.g., footwear and apparel), have not caused the trade imbalance between the two countries, because the exports share of these products has been decreased. Considering the fact that this specialization process is associated with an increase in trade volume between the two countries (or trade liberalization), it is necessary to discuss the relevant theories that suggest a connection between trade liberalization and changes in trade flows.

In fact, two types of trade can increase under trade liberalization: inter- and intra-industry trade. Inter-industry trade depends on the initial level of factor endowments. For instance, a capital abundant country such as the United States is expected to be a net exporter of capital-intensive products and a net importer of labor-intensive products under trade liberalization. Because this form of trade heavily depends on differences in initial resource endowments, an increase in trade volume due to a reduction in trade barriers does not drastically change the pattern of trade. Simply, an increase of trade volume means an increase in one-directional exports (or imports).

In the case of intra-industry trade, there are two types of explanations for why countries trade similar goods with each other. In fact, these two explanations predict different effects of trade liberalization on intra-industry trade. Under the increasing returns to scale (IRS) model of Krugman (1980), products are expected to be produced under an IRS technology. Due to the economies of scale, neither country is able to produce the full range of products by itself; thus, countries produce only a part of the possible range of products even though they are similar (product differentiated goods), and trade with each other. Trade barriers prevent countries from specialization, so they produce most of goods for their own needs. However, when trade barriers are reduced, countries start to specialize in production due to economies of scale and trade with each other. Therefore, an increased trade volume due to the reduction of trade barriers will result in substantial changes in the pattern of trade until a perfect specialization is reached. Under the IRS assumption, a reduction in trade barriers induces firms relocate to the larger market due to the economies of scale and transportation costs. This suggests a possibility that the larger country enjoys more than a one-to-one increase of exports, known as the home market effect of trade liberalization (Head and Ries 2001). Under this model, it is expected that the United States will enjoy more gains from trade liberalization with China for industries producing differentiated goods. However, there are two situations in which the home market effect can be reversed even

if the goods are produced under an IRS technology. First, in the short-run, firms producing differentiated goods cannot relocate easily, so the number of firms is fixed. In this case, trade liberalization enables the firms in a small country to increase its market share in a larger country simply because it improves access to the consumers in the larger foreign market. Therefore, a smaller country may be the net exporter of these types of goods.<sup>5</sup>

Second, Davis (1998) shows that transportation costs play an important role in deriving the home market effect in the IRS model. Without substantial differences in transportation costs between homogenous and differentiated products trade, producers do not have any particular motivation to move their firms to the larger market. For example, the difference in wages between the United States and China is large. If the wage difference between two countries in producing an industry exceeds transportation costs, U.S. firms move to China even though the U.S. market is larger. In this case, a reverse home market effect could occur. The increase in inward foreign direct investment (FDI) to China since 1995, in fact, supports this possibility.

On the other hand, under the national product differentiated (NPD) model, goods such as agricultural products are distinguished by nationality (Armington 1969). For these types of good, intra-industry trade can occur without the economies of scale. Countries trade similar goods simply because they are imperfectly substitutable. Head and Ries (2001) show that the impact of liberalization on changes in the pattern of trade for these goods converges to the short-run IRS model: a smaller country gains from the trade liberalization. However, this prediction is based on the assumption of similar per capita incomes for the two trading partners. This does not fit the U.S.-Chinese trade since, in comparison with the United States, China's per capita income is still very low. In this case, the difference in per capita income levels between two countries might play an important role in explaining the pattern of trade in these types of goods. For example, in the case of agricultural products, China's lower initial per capita income combined with a higher economic growth rate could cause a higher increase in domestic demand for agricultural products (Engel's law). However, because the production of agricultural goods depends on immobile factors such as land and weather, a higher demand in China does not result in inducing new entry, even with the lower wage level. Therefore, relatively high demand for agricultural products in China may simply be associated with a more than proportionate increase in imports from the United States in response to an increase in trade volume in these products. Due to different theoretical models predicting different effects of trade liberalization, which country (or industries) actually gains more from bilateral trade liberalization is ultimately an empirical question.

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<sup>5</sup> Head and Ries (2001) consider U.S.-Canadian trade under CUSTA, and find there is a 'reverse home market' effect in manufacturing trade in the short-run, while there is a 'home market' effect in the long-run. The result implies a disproportionate increase in U.S. exports to Canada for manufacturing goods in response to an increasing trade volume in the short-run, although goods are expected to be produced under IRS technology.

## EMPIRICAL MODELS

Due to the serious data limitation preventing the construction of a structural model, this study develops the following parsimonious reduced form equations.<sup>6</sup>

$$\ln(I_{it}^k) = \mu_i^k + \beta^k \ln(TV_{it}^k) + \gamma^k \ln(RE_t^{UC}) + \delta^k \ln(WRE_t^{UA}) + \lambda^k D^{94} + v_{it}^k, \quad (1)$$

where  $I_{it}^k$  is volume of exports from China to the United States for industry  $i$  in group  $k$  at time period  $t$ ;  $TV_{it}^k$  is total trade volume (exports from the United States to China plus exports from China to the United States) between the two countries for industry  $i$  in group  $k$  at time period  $t$ ;  $RE_t^{UC}$  is real exchange rate between the United States and China at time  $t$ ;  $WRE_t^{UA}$  is trade weighted real exchange rate between the United States and East Asian country at time  $t$ ; and  $D^{94}$  is a dummy variable indicating fixed exchange rate regime of China, which is zero before 1994 and one after 1994. The groups considered in this study are FBT ( $k=1$ ), Mid-tech manufacturing ( $k=2$ ), and High-tech manufacturing ( $k=3$ ).<sup>7</sup>  $\mu_i^k$  is industry specific unobservable latent effects. Finally,  $\ln$  stands for natural logarithm.

The variable,  $\ln(TV_{it}^k)$ , is expected to have an important role in isolating the effect of trade liberalization on changes in the pattern of trade from the bilateral exchange rate effect. In fact, there are many potential factors such as tariff and non-tariff barriers affecting a degree of trade liberalization. However, the purpose of the study is not to identify these factors but to estimate the effect of the bilateral exchange rate on the pattern of trade after isolating the effect of these factors. Moreover, it is natural to believe that a reduction of all unidentified trade barriers is realized through an increase in trade volume between countries. Therefore, by including  $\ln(TV_{it}^k)$  in an empirical model, we can capture the effect of trade liberalization on changes in the pattern of trade.

If an increase in bilateral intra-industry trade volume in industry group  $k$  has been associated with more (less) than proportionate increases of Chinese export to the United States, the estimated coefficient on  $\ln(TV_{it}^k)$  is expected to be more (less) than one. The coefficients are expected to differ between different industry groups because different theoretical models predict different relationship between variables.<sup>8</sup> If the U.S.-Chinese real exchange rate plays an

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<sup>6</sup> The movements of exchange rate between the United States and Asian countries are similar during the sample, which cause a serious multicollinearity problem. Therefore, we do not include and estimate all the US-Asian country's exchange rate simultaneously. In fact, the estimated coefficients, putting all the exchange rate simultaneously, are not within acceptable ranges and the signs are not consistent with our prior expectation due to the multicollinearity problem.

<sup>7</sup> Details of the industries included in the regression analysis are presented in the Appendix.

<sup>8</sup> According to the empirical model suggested by Head and Ries (2001), the production share of the larger country should increase faster (or slower) than its expenditure share for goods produced under IRS (or

important role in explaining the level of China's export to the United States, the estimated coefficient on  $RE_t^{UC}$  is expected to be significant and have a positive sign<sup>9</sup>. If the real appreciation of the U.S. dollar compared to South-East Asian countries primarily explain the level of Chinese exports to the United States, the estimated coefficients on  $WRE_t^{UA}$  are expected to be significant and have a positive sign. Finally, if China's exchange rate regime is important in explaining China's exports, the expected coefficient on  $D^{94}$  is positive.

Equation (1) is an indirect way of examining the trade imbalance problem between the United States and China because the dependent variable represents only China's exports to the United States. For instance, an increase in China's export to the United States in response to a real appreciation of the U.S. dollar does not exactly mean it is the precise cause of the trade imbalance problem between the two countries. To evaluate the trade imbalance between the two countries, the dependent variable in Equation (1) is divided by the total trade volume ( $TV_{it}^k$ )<sup>10</sup> as follows:

$$\left( \frac{I_{it}^k}{TV_{it}^k} \right) = \mu_i^k + \beta^k \ln(TV_{it}^k) + \gamma^k \ln(RE_t^{UC}) + \delta^k \ln(WRE_t^{UA}) + \lambda^k D^{94} + v_{it}^k. \quad (2)$$

In this model, the dependent variable is the share of Chinese exports to the United States as a portion of the total bilateral trade volume for industry  $i$  in group  $k$  at year  $t$ . If an increase in bilateral intra-industry trade volume in sector  $i$  in group  $k$  has been associated with more (less) than proportionate increases of Chinese exports to the United States, the estimated coefficient on  $\ln(TV_{it}^k)$  is now expected to be positive (negative).<sup>11</sup> If the estimated coefficient is positive, it implies that China benefits more from bilateral trade liberalization than the U.S. does. On the other hand, if it is negative, it means that the U.S. enjoys a greater gain.

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NPD) model. It is intuitive that this relationship can be sustainable only when export of the larger country increase faster (slower) than the total trade volume between the two countries.

<sup>9</sup> A high value of exchange rate means a real appreciation of the U.S. dollar by data construction.

<sup>10</sup> The dependant variable is already a share form, so we do not take natural logarithms in this model. A unit change in the left hand side variables are approximately a percent change due to the natural logarithm. Therefore, the estimated slope coefficients represent elasticity estimates approximately.

<sup>11</sup> In this model specification, the correlation between one of the instrumental variables (sum of GDP of two countries) with the dependent variable is much weaker because there is no particular reason to believe that income growth rate affects the export share held by one particular country.

## DATA AND ESTIMATION METHODS

### *Data*

The World Bank provides U.S. and Chinese trade data classified according to the International Standard Industrial Classification (ISIC) at the four-digit level during the period 1988-1999.<sup>12</sup> The database provides bilateral trade flows in detailed four-digit ISIC industries expressed in thousands of U.S. dollars. In order to obtain enough observations for regression analysis and following a suggestion made by Feenstra, Markusen, and Rose (2001), we classified them into three different groups: FBT, Mid-Tech manufacturing, and High-Tech manufacturing products.<sup>13</sup> The FBT includes the food, beverage, and tobacco industries associated with 14 ISIC four-digit industries; with 12 years of bilateral trade data, the total number of observation for this sector is 168. The Mid-Tech manufacturing group includes the manufacturing industries using raw materials associated with 21 ISIC four-digit industries; the total number of observations for this sector is 252. Finally, the High-Tech manufacturing group includes sophisticated manufacturing industries such as machinery, transportation, and professional and scientific equipment. Five ISIC three-digit industries are included which are associated with 17 ISTC four-digit industries in this group, producing 204 observations.<sup>14</sup>

The bilateral real exchange rate between the United States and China, and those between the United States and other South-East Asian countries are obtained from Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA). Because the real exchange rates represent the U.S. dollar value compared to the currencies of other countries, an increase in the exchange rate index represents a real appreciation of the U.S. dollar. Finally, the weighing matrix to calculate the trade-weighted real exchange rate is also obtained from ERS in the USDA. The Weights are originally average dollar shares of U.S. exports for the commodity aggregation between 1998 and 2000. We recalculate the share to fit only Asian countries in our sample. The weights are: Thailand=0.057; Malaysia=0.075; Indonesia=0.031; Philippines=0.047; South Korea=0.216; Japan=0.573.

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<sup>12</sup> Originally, we have data from 1987 to 1999. However, we lost one observation for each industry due to the econometric procedure. The data is available at [www.worldbank.org/research/trade](http://www.worldbank.org/research/trade).

<sup>13</sup> Inter-industry trade includes two types of sectors: those that are net importers and those that are net exporters for the U.S. For instance, the United States does not export textile and footwear products to China, while China does not export some sophisticated manufacturing goods such as airplane. In this case, an increasing trade volume simply increases one-directional trade, resulting in no particular relationship between trade share of China and trade volume. Therefore, after eliminating these industries, we re-classified industry groups. Detailed industries included in the regression analysis are presented in Appendix.

<sup>14</sup> All the trade variables are deflated by the U.S. consumer price index (1990=100).

### Estimation Methods

The model specification has a potential endogeneity problem because the independent variable,  $\ln(TV_{it}^k)$ , could be correlated with the error term. It is known that the least squares estimator is biased in this case. The classical two-stage least squares (2SLS) estimator is consistent but not efficient due to the industry-specific unobservable latent effects  $\mu_i$ . To solve these problems, we utilize the estimation procedure introduced by Baltagi (1981). To explain the econometric procedure briefly and for notational simplicity, we rewrite Equations (1) and (2) as

$$y = Z\theta + u \quad \text{and} \quad u = Z_\mu\mu + v, \quad (3)$$

where  $Z_\mu = I_N \otimes i_T$ ,  $I_N$  is the identity matrix of order  $N$ ,  $i_T$  is the vector of ones of order  $T$ , and  $\otimes$  stands for kronecker product.  $\mu = (\mu_1, \mu_2, \dots, \mu_N)$ ,  $v = (v_{11}, v_{12}, \dots, v_{NT})$  are random vectors with zero means and finite variances  $\sigma_\mu^2$  and  $\sigma_v^2$ , respectively.  $Z = [Y, \widehat{X}]$  where  $Y$  is the set of right-hand side endogenous variables and  $\widehat{X}$  is the set of exogenous variables included in model (3).  $\theta$  is a vector of unknown coefficients to be estimated. In our case, therefore,  $y = \ln(I_{it}^k)$  or  $y = \left( \frac{I_{it}^k}{TV_{it}^k} \right)$ ,  $Y = \ln(TV_{it}^k)$ , and  $\widehat{X} = [\ln(RE_t^{UC}), \ln(WRE_t^{UA}), D^{94}]$ .

Let  $X = [\widehat{X}, \widetilde{X}]$ , where  $\widetilde{X}$  is the set of available exogenous variables, which are strongly correlated with  $\ln(TV_{it}^k)$  but are not correlated with the error term. For estimation, two instrumental variables are chosen.<sup>15</sup> The first one is  $\ln(TV_{it-1}^k)$ , which is predetermined, so it could not be correlated with the error term, but is highly correlated with  $\ln(TV_{it}^k)$ . The second instrumental variable is log of the sum of real gross domestic products of the United States and China. According to studies using gravity type models (e.g., Glick and Rose 2001; Rose and Wincoop 2001), the sum of income between two trading countries is strongly correlated with trade volume between the countries; however, the correlation is expected to be weak with export performance held by one particular country in model specification (1), and much weaker in model specification (2) because there is no particular reason to believe that income growth rate affects the export share of a specific country.

The covariance matrix of (3) becomes,

$$\Omega = E(uu') = \sigma_\mu^2(I_N \otimes I_T) + \sigma_v^2 I_{NT}, \quad (4)$$

where  $I_T$  and  $I_{NT}$  are identity matrices of order  $N$  and  $NT$ . One can transform (3) by  $Q = I_{NT} - P$  where  $P = Z_\mu(Z_\mu'Z_\mu)^{-1}Z_\mu$ , and obtain

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<sup>15</sup> Due to data limitations, the choice of instrumental variables is highly limited.

$$Qy = QZ + Qu. \quad (5)$$

Let  $\tilde{y} = Qy$  and  $\tilde{Z} = QZ$ . Perform 2SLS on (5) with  $\tilde{X} = QX$  as the set of instruments, we have within two-stage least squares estimator (W2SLS)

$$\tilde{\theta}_{W2SLS} = (\tilde{Z}' P_{\tilde{X}} \tilde{Z})^{-1} \tilde{Z}' P_{\tilde{X}} \tilde{y}, \quad (6)$$

where  $P_{\tilde{X}} \tilde{Z} = \tilde{X} (\tilde{X}' \tilde{X})^{-1} \tilde{X}' \tilde{Z}$ . In this case,  $Var(\tilde{\theta}_{W2SLS}) = \sigma_v^2 (\tilde{Z}' P_{\tilde{X}} \tilde{Z})^{-1} \tilde{Z}' P_{\tilde{X}} \tilde{y}$ . Similarly, if we transform (3) by  $\bar{y} = Py$  and  $\bar{Z} = PZ$  with  $\bar{X} = PX$  as the set of instruments, we can obtain the between two stage least squares estimator (B2SLS)

$$\hat{\theta}_{B2SLS} = (\bar{Z}' P_{\bar{X}} \bar{Z})^{-1} \bar{Z}' P_{\bar{X}} \bar{y}, \quad (7)$$

where  $P_{\bar{X}} \bar{Z} = \bar{X} (\bar{X}' \bar{X})^{-1} \bar{X}' \bar{Z}$ ,  $Var(\theta_{B2SLS}) = \sigma_v^2 (\bar{Z}' P_{\bar{X}} \bar{Z})^{-1} \bar{Z}' P_{\bar{X}} \bar{y}$ .

Baltagi (1981) shows that we can obtain the error component two-stage least squares estimator (EC2SLS), stacking two transformed Equations (6) and (7) as a system,

$$\begin{pmatrix} \tilde{X}' \tilde{y} \\ \bar{X}' \bar{y} \end{pmatrix} = \begin{pmatrix} \tilde{X}' \tilde{Z} \\ \bar{X}' \bar{Z} \end{pmatrix} \theta + \begin{pmatrix} \tilde{X}' \tilde{u} \\ \bar{X}' \bar{u} \end{pmatrix}, \quad (8)$$

where  $E \begin{pmatrix} \tilde{X}' \tilde{u} \\ \bar{X}' \bar{u} \end{pmatrix} = 0$  and  $Var \begin{pmatrix} \tilde{X}' \tilde{u} \\ \bar{X}' \bar{u} \end{pmatrix} = \begin{bmatrix} \sigma_v^2 \tilde{X}' \tilde{X} & 0 \\ 0 & \sigma_1^2 \bar{X}' \bar{X} \end{bmatrix}$ .

Performing GLS on (8) yields the EC2SLS estimator of  $\theta$ , which is more efficient than W2SLS if the industry-specific latent effects are not correlated with the error term. That is

$$\hat{\theta}_{EC2SLS} = \left[ \frac{\tilde{Z}' P_{\tilde{X}} \tilde{Z}}{\sigma_v^2} + \frac{\bar{Z}' P_{\bar{X}} \bar{Z}}{\sigma_1^2} \right]^{-1} \left[ \frac{\tilde{Z}' P_{\tilde{X}} \tilde{y}}{\sigma_v^2} + \frac{\bar{Z}' P_{\bar{X}} \bar{y}}{\sigma_1^2} \right]. \quad (9)$$

Unknowns are  $\sigma_1^2$  and  $\sigma_v^2$ . For the feasible GLS, consistent estimators are obtained from the residuals of the W2SLS and B2SLS,

$$\hat{\sigma}_v^2 = \frac{\tilde{u}' \tilde{u}}{N(T-1)} \text{ and } \hat{\sigma}_1^2 = \frac{\bar{u}' \bar{u}}{N}, \quad (10)$$

where  $\tilde{u}$  are residuals from W2SLS and  $\hat{u}$  are residuals from B2SLS.<sup>16</sup> In fact, both W2SLS and EC2SLS estimators are more efficient than the classical 2SLS estimator.

### ESTIMATION RESULTS

Table 1 presents the estimated coefficients of the model 1. For comparison, results of both W2SLS and EC2SLS estimators are presented<sup>17</sup>. For the FBT group, 14 intra-industry trades are included and the most influential industry is agriculture. Therefore, the results of this group can be considered as evidence of agricultural trade. In the case of the estimated coefficients on the volume of bilateral trade [ $\ln(TV_{it}^k)$ ], all are less than one and statistically significant at the 1 percent level. W2SLS and EC2SLS give us quite similar estimates (0.712 and 0.814). The results imply that a 1 percent increase in the bilateral trade volume in this group has been associated with only a 0.709~0.819 percent increase in China's exports to the United States, indicating a less than one-to-one increase in exports by China in response to trade liberalization. Therefore, we can conclude that the direction of specialization under trade liberalization is favorable to the United States. As discussed earlier, these results might be due to the substantial difference in per capita income between the two countries associated with immobile factors of production such as land and climate.

Table 1. Estimation Results of Model Specification (1)

		Constant	$\ln(TV_{it}^k)$	$\ln(RE_t^{UC})$	$\ln(WRE_t^{UA})$	$D^{94}$	$R^2$
FBT	W2SLS	-5.231 (-0.85)	0.712 <sup>a</sup> (4.70)	0.465 (0.55)	0.934 (1.12)	0.691 <sup>a</sup> (2.79)	0.318
	EC2SLS	-6.105 (-1.00)	0.814 <sup>a</sup> (7.26)	0.519 (0.61)	0.911 (1.09)	0.611 <sup>a</sup> (2.61)	---
Middle-Tech	W2SLS	-6.648 <sup>b</sup> (-2.34)	1.034 <sup>a</sup> (17.4)	0.431 (1.10)	0.724 <sup>c</sup> (1.85)	0.623 <sup>a</sup> (4.84)	0.787
	EC2SLS	-6.627 <sup>b</sup> (-2.34)	1.030 <sup>a</sup> (21.4)	0.432 (1.10)	0.727 <sup>c</sup> (1.86)	0.629 <sup>a</sup> (5.24)	---
High-Tech	W2SLS	-11.80 <sup>a</sup> (-5.58)	1.075 <sup>a</sup> (16.7)	0.820 <sup>a</sup> (2.77)	1.321 <sup>a</sup> (4.44)	0.558 <sup>a</sup> (5.19)	0.869
	EC2SLS	-11.80 <sup>a</sup> (-5.58)	1.076 <sup>a</sup> (18.2)	0.819 <sup>a</sup> (2.78)	1.319 <sup>a</sup> (4.46)	0.556 <sup>a</sup> (5.40)	---

Notes: z-statistics are in parentheses; a, b, and c denote significance at the 1, 5, and 10 percent levels.

<sup>16</sup> More detailed discussion of these procedures can be found in Baltagi (2001). To implement these procedures, a STATA module (xtivreg) was used.

<sup>17</sup> As Head and Ries and others indicate, within 2SLS results could be interpreted as short-run relationship, while EC2SLS results may represent medium-run relationship between variables.

In the case of the bilateral exchange rate for the FBT group, we do not find any statistically significant relationship between the variables. Similar results are also obtained in the case of exchange rate between the United States and South-East Asian countries. We do not find any significant exchange rate effect on the performance of Chinese exports to the United States. In the case of the exchange rate regime dummy variable, however, the estimated coefficients are positive and statistically significant at the 1 percent level, implying that China's exchange rate regime had some role in explaining China's export to the United States. However, although China's exchange rate regime changed in 1994, the dramatic increase in trade volume between the two countries also began in the mid-1990s. Therefore, with a relatively short span of data, it is difficult to determine whether the positive estimates result from the exchange rate regime shift or trade liberalization.

In the case of the Mid-Tech group, we have an exact reverse in the relationship between bilateral trade volume and exports by China. All the estimated coefficients are larger than one and statistically significant. The estimated coefficients are 1.030 and 1.034, meaning that a 1 percent increase in bilateral trade volume corresponds to a 0.030~0.034 percent increase in trade share held by China, implying a more than one-to-one increase in China's exports. Therefore, we conclude that China has benefited more from trade liberalization in these industries. Another important finding is that, similar to the FBT sector, we do not find any significant bilateral exchange rate effects, while we find weak evidence of third country exchange rate effects. The estimated coefficients on the exchange rate between the United States and South-East Asian countries are positive but significant at the 10 percent levels. The estimated coefficients on the dummy variable are positive and significant in all cases.

The results for the High-Tech group are also presented in Table 1. The estimated coefficients on trade volume are all more than one and highly significant. The magnitude of the coefficients (1.075~1.076) is much larger than those for the Mid-Tech group. In terms of the exchange rate effect, however, the results are quite different from the previous two groups. The estimated coefficients on the bilateral exchange rate between the United States and China are statistically significant at the 1 percent level. However, considering the fact that the real exchange rate between the United States and China has been relatively stable during the sample period, we do not expect it to generate a significant impact on the trade imbalance problem between the two countries. In the case of the exchange rate between the United States and South-East Asian countries, the estimated coefficients are statistically significant at the 1 percent level. The magnitudes of the relative exchange rate effects are bigger than those of the bilateral exchange rates. As mentioned earlier, unlike the bilateral exchange rate, the real exchange rate between the United States and South-East Asian countries has changed drastically during the sample period. Our empirical results imply that a 50 percent real appreciation of the U.S. dollar compared to the currencies of these countries has been associated with more than a 50 percent increase in China's exports to the United States in these products.

The estimation results of model 2 for each group are presented in Table 2. As a whole, the results give us a conclusion quite similar to that of model 1. The estimated coefficients of  $\ln TV_{it}$  for the FBT group are all negative (-0.037 and -0.038), while they are all positive in the case of Mid-tech (0.032 and 0.045) and High-tech (0.071 and 0.077) manufacturing groups. The negative (positive) coefficient indicates that China's export share increases less (more) than proportionately in response to an increase of trade volume between the countries. The big differences are the impact of the bilateral exchange rate. Even in the case of the High-tech manufacturing group, we cannot find any statistically significant relationship between the variables. As mentioned earlier, a potential reason for this weak relationship is the relatively stable real exchange rate between the two countries during the sample period. Even though the bilateral exchange rate is important for explaining China's exports to the United States for these products, the realization of the exchange rate during the sample period might not be large enough to cause a trade imbalance. However, in the case of the third country exchange rates, all the estimated coefficients are statistically significant, which could be due to their large fluctuation during the sample period.

Table 2. Estimation Results of Model Specification (2)

		Constant	$\ln(TV_{it}^k)$	$\ln(RE_t^{UC})$	$\ln(WRE_t^{UA})$	$D^{94}$	$R^2$
FBT	W2SLS	0.128 (0.15)	-0.038 <sup>c</sup> (-1.76)	0.106 (0.88)	0.086 (0.72)	0.051 (1.44)	0.033
	EC2SLS	0.115 (0.13)	-0.037 <sup>c</sup> (1.88)	0.107 (0.89)	0.086 (0.72)	0.050 (1.44)	---
Middle-Tech	W2SLS	-0.705 (-1.06)	0.045 <sup>a</sup> (3.25)	-0.002 (-0.02)	0.114 (1.25)	0.088 <sup>a</sup> (2.90)	0.235
	EC2SLS	-0.634 (-0.95)	0.032 <sup>a</sup> (2.58)	0.004 (0.00)	0.124 (1.35)	0.105 <sup>a</sup> (3.60)	---
High-Tech	W2SLS	-1.874 <sup>a</sup> (-3.59)	0.077 <sup>a</sup> (4.82)	0.046 (0.63)	0.205 <sup>a</sup> (2.79)	0.063 <sup>b</sup> (2.39)	0.456
	EC2SLS	-1.851 <sup>a</sup> (-3.52)	0.071 <sup>a</sup> (4.74)	0.049 (0.68)	0.211 <sup>a</sup> (2.88)	0.070 <sup>a</sup> (2.71)	---

Notes: z-statistics are in parentheses; a, b, and c denote significance at the 1, 5, and 10 percent levels.

As a whole, the relationship between third country exchange rates and the U.S.-China bilateral trade flows is significant for the High-tech manufacturing group. The relationship is not significant for the case of the FBT group and is marginally significant for the Mid-tech manufacturing group. As indicated by McKinnon and Schnabl (2003), most of the Chinese imports from South-East Asian countries are intermediate (raw materials) goods for producing High-tech manufacturing products. In this case, there is a possibility that high purchasing power of Chinese currency relative to these Asian countries causes more imports of intermediated manufacturing goods from these countries, resulting in more export of final manufacturing goods to the United States.

## CONCLUSION

Since 1990, China's economic growth has been aided by large inflows of foreign direct investment. These have been coupled with trade surpluses, leading to substantial balance-of-payments surpluses, especially with the United States. Because China has kept its currency fixed since 1994 to the U.S. dollar, its large trade surplus with the United States has led many critics to claim that the yuan is undervalued. In this paper, we examine the effect of the bilateral exchange rate between the United States and China on the trade imbalance problem between the two countries. Using a pooling of cross-sectional and time-series data over the period 1987-1999, we reach two important conclusions.

First, the exchange rate (both bilateral and relative exchange rate) does not have an important role in explaining bilateral trade between the two countries except for High-tech manufacturing products. In the case of High-tech manufactured products, the relative exchange rate between the United States and the South-East Asian countries are important in explaining the trade imbalance problem between the United States and China. Considering the fact that the U.S.-Chinese trade imbalance problem heavily depends on the dramatic increase in China's share of High-tech manufactures trade, this study suggest that a real depreciation of the U.S. dollar against the currencies of the South-East Asian countries would be more helpful for solving the trade imbalance problem between the two countries.

Second, a less than one-to-one increase in China's trade share in response to increasing trade volume (or trade liberalization) is found for relatively homogenous products, such as agricultural goods, while a more than one-to-one increase in China's trade share in response to increasing trade volume is found in the most of manufactured products, especially sophisticated manufactured products. In fact, these results support the view that trade integration with China would lead to a loss of jobs in the United States. However, as Gabriel (2003) notes, consumers in the United States could gain due to the cheaper manufacturing goods imported from China. Finally, the U.S. agricultural sector is expected to gain from bilateral trade with China under the process of trade liberalization.

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## Appendix: The ISIC Classification

### ISIC 3 digit description for data analysis

#### FBT Sector

- 311 Food products
- 313 Beverages
- 314 Tobacco

#### TALF Sector

- 321 Textiles
- 322 Wearing apparel except footwear
- 323 Leather products
- 324 Footwear except rubber or plastic

#### Middle-Tech Manufacturing Sector

- 331 Wood products except furniture
- 332 Furniture except metal
- 341 Paper and products
- 342 Printing and publishing
- 351 Industrial chemicals
- 352 Other chemicals
- 353 Petroleum refineries
- 354 Miscellaneous petroleum and coal products
- 355 Rubber products
- 356 Plastic products
- 361 Pottery china earthenware
- 362 Glass and products
- 369 Other non-metallic mineral products
- 371 Iron and steel
- 372 Non-ferrous metals
- 381 Fabricated metal products

#### High-Tech Manufacturing Sector

- 382 Machinery except electrical
- 383 Machinery electric
- 384 Transport equipment
- 385 Professional and scientific equipment
- 390 Other manufactured products

## ISIC 4 digit description and industries included in regression analysis

### FBT Sector (14 industries)

- 3111 Slaughtering preparing and preserving meat
- 3112 Manufacture of dairy products
- 3114 Canning preserving and processing of fish crustacean and similar foods
- 3115 Manufacture of vegetable and animal oils and fats
- 3116 Grain mill products
- 3117 Manufacture of bakery products
- 3118 Sugar factories and refineries
- 3121 Manufacture of food products not elsewhere classified
- 3122 Manufacture of prepared animal feeds
- 3131 Distilling rectifying and blending spirits
- 3132 Wine industries
- 3133 Malt liquors and malt
- 3134 Soft drinks and carbonated waters industries
- 3140 Tobacco manufactures

### Middle-Tech Manufacturing (21 industries)

- 3211 Spinning weaving and finishing textiles
- 3219 Manufacture of textiles not elsewhere classified
- 3232 Fur dressing and dyeing industries
- 3311 Sawmills planing and other wood mills
- 3412 Manufacture of containers and boxes of paper and paperboard
- 3419 Manufacture of pulp paper and paperboard articles not elsewhere classified
- 3420 Printing publishing and allied industries
- 3511 Manufacture of basic industrial chemicals except fertilizers
- 3522 Manufacture of drugs and medicines
- 3523 Manufacture of soap and cleaning preparations perfumes cosmetics and other
- 3529 Manufacture of chemical products not elsewhere classified
- 3530 Petroleum refineries
- 3540 Manufacture of miscellaneous products of petroleum and coal
- 3551 Tyre and tube industries
- 3559 Manufacture of rubber products not elsewhere classified
- 3620 Manufacture of glass and glass products
- 3691 Manufacture of structural clay products
- 3692 Manufacture of cement lime and plaster
- 3699 Manufacture of non-metallic mineral products not elsewhere classified
- 3710 Iron and steel basic industries
- 3720 Non-ferrous metal basic industries

### High-Tech Manufacturing (17 industries)

- 3812 Manufacture of furniture and fixtures primarily of metal
- 3813 Manufacture of structural metal products
- 3819 Manufacture of fabricated metal products except machinery and equipment
- 3821 Manufacture of engines and turbines
- 3822 Manufacture of agricultural machinery and equipment
- 3823 Manufacture of metal and woodworking machinery
- 3824 Manufacture of special industrial machinery and equipment except metal and wood
- 3825 Manufacture of office computing and accounting machinery

3829 Machinery and equipment except electrical not elsewhere classified  
3831 Manufacture of electrical industrial machinery and apparatus  
3832 Manufacture of radio television and communication equipment and apparatus  
3839 Manufacture of electrical apparatus and supplies not elsewhere classified  
3841 Shipbuilding and repairing  
3842 Manufacture of railroad equipment  
3843 Manufacture of motor vehicles  
3851 Manufacture of professional and scientific and measuring and controlling equipment  
3852 Manufacture of photographic and optical goods