MEASURING THE TECHNOLOGY CONTENT OF CHINA'S EXPORTS

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June 2006

Abstract

This paper constructs a measure of technology content of exports (TCE) and applies it to China. There have been increasing concerns in China about its exports being mainly on the low end. Recent research found however that China's exports were much more sophisticated than its development level implies, yet carried exceptionally high price discounts. Our TCE measure incorporates in one index the technology sophistication ranking across products and the quality ranking of country varieties within product. Using TCE indices we reexamine the features of China's exports found in earlier studies and identify several new features. We find that after the mid 1990s China's country-level TCE became compatible to its development level. China's product-level TCE was significantly below the benchmark and the gap had been widening over 1991-2001. At both the industry and product levels we find a positive correlation between export-share growth and TCE level. This export-share effect appeared to be the main force sustaining China's overall TCE growth.

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1. Introduction

Exports are an important part in the success story of China's economic growth. From 1978 to 2005, China's GDP (current value) increased from 362 billion yuan to 18.23 trillion yuan, an average annual growth rate of 15 percent.[1] During the same period, China's export volume increased from $9.75 billion to $762 billion, an average annual growth rate of near 17 percent.

How have exports contributed to China's economic growth? Recently the focus has been on the "quality" of Chinese exports. There are increasing concerns among Chinese officials, media and the public that China has been exporting mainly "low-end" products. Reflecting such concerns, China's Premier Wen Jiabao, in his 2006 government work report on China's eleventh five-year plan (2006-2010), emphasized that China needs to "change the pattern of growth of foreign trade, improve the mix of imports and exports, … support the export of service products and high value-added products with Chinese intellectual property rights and trademarks,… speed up the process of upgrading the processing trade".

Has China been exporting mainly "low-end" products? A recent paper by Rodrik (2006) argues that the opposite is true. Rodrik (2006) uses a measure that ranks goods by its "income content", which was developed by Hausmann, Hwang, and Rodrik (2005). Simply put, this measure defines the sophistication of a good according to the real GDP per capita levels of its exporters. Computing the average income content of Chinese exports, Rodrik (2006) finds that "China is an outlier in terms of the overall sophistication of its exports: its export bundle is that of a country with an income-per-capita level three times higher than China's" (p. 4).

[1] In December 2005, China revised its 2004 GDP to 15.99 trillion yuan, an increased of 16.8 percent. Over 90 percent of the newly-added 2.3 trillion yuan is from better data about the services sector.

Schott (2006) is another paper that examines the sophistication of Chinese exports. Utilizing the export similarity index (ESI) of Finger and Kreinin (1979), Schott (2006) measures the similarity of Chinese exports (to the U.S.) with that of the OECD, and finds that "China's ESI with the OECD is on average 0.39 and 0.27 higher than for countries with similar PCGDP and skill abundance, respectively" (p. 12). Schott (2006) finds, however, that while the export similarity of Chinese exports with the OECD has been increasing, "Chinese products on average sell for a discount relative to their PCGDP and skill abundance" (p.14).

The evidence from Rodrik (2006) and Schott (2006) reveals two features of Chinese exports. First, China has been exporting more and more goods that belong to "high-end" product categories, and the degree of sophistication of China's exports is significantly higher than what its development level implies. Second, within product category, Chinese varieties are on average on the "low-end" (if price signals quality) as they sell at significantly lower prices. Rodrik (2006), by ignoring the product quality dimension, is likely to have overestimated the sophistication level of Chinese exports. Schott (2006) did examine both the product-mix dimension and the product-quality dimension; without connecting them, however, Schott (2006) did not provide us with an assessment of the overall sophistication of Chinese exports.

In this paper we incorporate *in one index* the technology sophistication ranking across products and the quality ranking across country varieties within product. The index has two components, a base and a multiplier. The base is the income content measure of Hausmann, Hwang, and Rodrik (2005), which captures a product's *average* technology level associated with the development levels of all its exporting countries. The multiplier is a relative-quality measure, which captures the technology level implied in the quality of a country's product relative that of the other exporting countries. The quality multiplier adjusts up the technology content of high-quality varieties above the average technology level of the product, and adjusts down the technology content of low-quality varieties below the average technology level of the product. We term the index "Technology Content of Exports" (TCE), which yields a distinctive value for each country-product observation.

We compute the TCE index for Chinese manufacturing exports to the U.S. at the 10-digit level of Harmonized System (HS10) in the period 1989-2001, using U.S. import data documented in Feenstra, *et al* (2002) and real GDP per capita data from Penn World Table 6.1. We aggregate the TCE indices of HS-products to the ISIC industry level and to the country level. Equipped with the TCE indices at the product, industry, and country levels, we reexamine the features of the Chinese exports found in the earlier studies, and identify some new features.

First, we reexamine the finding of Rodrik (2006) that China is an outlier in terms of technology sophistication of exports. Without adjusting product quality in the measurement, our data confirms Rodrik's finding: China is an outlier in every year from 1989 to 2000. However, using our quality-adjusted measure of TCE, China disappeared to be an outlier after the mid 1990s. This result highlights the importance of considering the product quality dimension in evaluating the technology content of China's exports. By ignoring the low quality nature of Chinese exports, Rodrik (2006) overestimated the technology sophistication of Chinese exports.

Second, we find that the product-level TCE of China is significantly lower than that of a country at the same development level in every year from 1991 to 2001. Moreover, the gap had been widening steadily during the period. Low TCE at the product level is driven by low product quality. This result is a mirror image of Schott's (2006) finding of increasing price discounts of Chinese exports.

In the paper we identify several new features that help to explain the pattern and trend of the technology content of Chinese exports. First, at both the industry and product levels, we find a positive correlation between the growth rate of an industry/product's export share (in China's total exports) and its TCE level. On average, industries/products with higher TCE levels expanded more in exports. Our analysis indicates that this export-share effect was the main force that drove China's overall TCE to increase by 17 percent relative to that of the world in the period 1989-2001. It raises an important question for future research to explore the reasons behind this positive correlation and assess the potential for this trend to continue.

Second, we find that the average TCE of the products China added to its export bundle over 1990-2001 is significantly higher than the average TCE of the products China exported in 1989. This average masks, however, a sharp difference between the first half of the 1990s and the second half. In the first half of the 1990s, the products that China added yearly to its export basket had higher TCE levels than the products already in exporting. In sharp contrast, in the second half of the 1990s, the products that China added yearly to its export basket had lower TCE levels than the products already in exporting. This finding helps to explain why China was an outlier in terms of overall TCE in the first half of the 1990s, but stopped to be so after 1996. It again raises an important question for future research to examine the reasons behind this pattern and to evaluate if this trend will continue.

We organize the remainder of the paper as follows. In section 2 we discuss the methodology for constructing the TCE index. In section 3 we discuss the data and computational issues. In section 4 we use TCE indices to identify several features in the evolvement of China's technology content of exports. In section 5 we conclude. The appendix provides detailed information on the data.

2. Methodology

In this section we discuss the methodology for measuring the technology content of exports of a country.

Trade models identify goods by labor productivity (Ricaridan model), factor intensity (H-O model), variety and quality (monopolistic competition models), and by associating them with heterogeneous firms (Melitz, 2003). Combining the insights of all trade models, the same good from different countries can be quite distinctive. In trade data, goods identify themselves by commodity classification. As Schott (2004) shows, even at the very detailed commodity classification level of HS10 (Harmonized System 10-digit level), there still exists considerable heterogeneity.

Hausemann, Hwang and Rodrik (2005) propose to rank goods in terms of their "per capita income content". The higher is the GDP per capita of the countries exporting a good, the higher the "per capita income content" of this good. Their measure, which they term PRODY, can be expressed as

$$\text{PRODY}_i = \sum_c \left\{ \frac{x_{ic} / \sum_k x_{kc}}{\sum_m (x_{im} / \sum_k x_{km})} Y_c \right\} \qquad (1)$$

In this equation, Y_c is country c's real GDP per capita. The ratio in front of Y_c serves as a weight. The numerator of the weight ($x_{ic}/\Sigma x_{kc}$) is the export share of good i in country c's total exports; the denominator is the sum of export shares of all the countries exporting good i, so that the sum of the weights equals one. Thus PRODY_i is a trade-importance-weighted average of real GDP per capita of all the countries that export good i. If the technology level of a good is an increasing function of the real GDP per capita levels of the countries that export it, then PRODY can serve as a measure of the good's technology content.

PRODY$_i$ is identical for good i regardless of its exporting country. The evidence (U.S. General Accounting Office, 1995; Schott, 2004) indicates however that even at the commodity classification level of HS10, the same HS10 code covers products of different quality associated with the identity of the exporting countries. To capture this quality dimension, we define the following index that measures the relative unit value of country c's exported good i:

$$Q_{ic} = \frac{u_{ic}}{\sum_n \left\{ \frac{x_{in}}{\sum_k x_{ik}} u_{in} \right\}} \qquad (2)$$

In this equation, u_{ic} denotes the unit value of good i exported by country c. The denominator is the weighted average of unit values of good i exported by all countries, the weight being country n's export share of good i in all countries' exports of good i, which reflects the relative importance of country n in exporting good i.

This cross-country quality differences within a product category need to be considered in measuring the technology content of an exported good. We propose to introduce a "quality multiplier" that adjusts the PRODY index of Hausemann, Hwang and Rodrik (2005). PRODY measures the *average* technology content of a good without considering within-product quality differences. To capture both the technology content differences across products and the technology content differences within product, we define an index of "technology content of exports" as

$$TCE_{ic} = m_i(Q_{ic})\ PRODY_i \qquad (3)$$

where TCE_{ic} denotes the technology content of good i exported by country c, and m(.) is a multiplier that is an increasing function of the relative unit value index Q. If good i from country c has high technology content, it can be because the good is ranked high by the average standard of technology sophistication ($PRODY_i$), or because the good is ranked high in quality relative to other countries (Q_{ic}), or because of both. The usefulness of this index is that it recognizes the relatively high technology content of a high-quality variety (e.g. men's cotton shirts made in Italy, Q=2.84 in 2001) that belongs to a product category of low technology sophistication (HS=6105100010, "Men's shirts of cotton, knit", PRODY=3,579 in 2001), and the relatively low technology content of a low-quality variety (e.g. video projectors made in China, Q=0.15 in 2001) that belongs to a product category of high technology sophistication (HS=8528304000, "Video projectors, CLR, non-hi def", PRODY=29,292 in 2001).

In computing the TCE index, we choose the following functional form:

$$TCE_{ic} = (Q_{ic})^{\theta} \times PRODY_i \qquad (4)$$

In this equation, θ is a parameter that determines the degree of quality adjustment; $TCE_{ic} = PRODY_i$ when $\theta = 0$.

We can aggregate TCE of individual goods to the levels of industry, country, and the world. For country c, its country-level TCE is given by

$$TCE_c = \sum_k \left\{ \frac{x_{kc}}{\sum_k x_{kc}} TCE_{kc} \right\} \qquad (5)$$

In this equation, country c's technology content of exports (TCE_c) equals the weighted average of the technology contents of all the exported goods of the country, the weight being the share of the corresponding exported good in the country's total exports. We compute the industry-level technology content of exports in a similar way, using industry export shares as weights.

3. Data and Computation

We use U.S. imports data (1989-2001) described in Feenstra, *et al* (2002). Goods are classified by HS10. We use data on manufactured goods only, which correspond to Industries 5-8 in SITC1 classification.

The dataset has information on each HS10 product's source country, value (x_{ic}) and quantity (q_{ic}), which allow us to compute unit value:

$$u_{ic} = x_{ic} / q_{ic} \qquad (6)$$

Using unit value data, we compute the quality index Q_{ic} according to equation (2).

There exist some extremely small and large values of Q_{ic} that are implausible. For example, in the 2001 dataset, the minimum Q_{ic} is 0.0000001 and the maximum is 37,267. U.S. General Accounting Office (1995) had an analysis of eight commodities in the 1992 dataset and found that one major reason for such extreme values is errors made by the filer when entering data (e.g., misclassifying the product or entering the wrong quantity or total value). To remove these erroneous values, we choose to drop the top 1 percentile and bottom 1 percentile of the data based on the value of Q_{ic}. Table A1 of the appendix reports summary statistics before and after this adjustment. After the adjustment the maximum and minimum values of Q_{ic} look much more plausible and are relatively stable across years. For example, in the 2001 dataset, the minimum Q_{ic} is now 0.008 and the maximum 87.26.

We use real GDP per capita data from Penn World Table 6.1 (PWT6.1). Previous studies (Rodrik, 2006; Schott, 2006) chose to use real GDP per capita data from the World Bank. Although the values of the two series are highly correlated (with a correlation of 0.94 in our sample), the World Bank GDP per capita is likely to underestimate China's development level. Table 1 reports China's real GDP per capita as a share in U.S. real GDP per capita using both data series. The World Bank data indicate that China's real GDP per capita is only 2.74 percent of the U.S.'s in 2000. By contrast, the PWT6.1 data indicate that China's real GDP per capita is 11.25 percent of the U.S.'s in 2000. We believe that the PWT6.1 data measure China's development level more accurately than the World Bank data. It is worth pointing out that an underestimated development level for China could artificially make China an outlier in a cross-country study that examines if the sophistication of China's exports is compatible to its development level.

[Table 1 about here]

Using U.S. import data and PWT6.1 real GDP per capita data we compute $PRODY_i$ for each HS product according to equation (1). As Hausemann, Hwang and Rodrik (2005) correctly noted, computation of $PRODY_i$ requires a consistent sample of countries in order to avoid possible biases. In our dataset we have 93 countries that have trade and GDP per capita data in every year from 1989 to 2001. We compute $PRODY_i$ using this sample of countries.

Our main task is to compute the "technology content of exports" index defined in equation (4), $TCE_{ic} = (Q_{ic})^{\theta} \times PRODY_i$. This requires choosing a proper value for θ. There is no theoretically "correct" value of θ. Our criterion is to find a value of θ that makes TCE best reflect the R&D content of industries, for which we have data.

R&D data are available for OECD countries at ISIC industry level. From China's national surveys of firms, we also obtain R&D data for China. These data allow us to compute R&D intensities (R&D spending divided by gross product, multiplied by 100) for 14 manufacturing industries of 19 countries. We run the following regression:

$$\ln (TCE_{jc}) = \alpha + \beta \ln (RDY_{jc}) + \varepsilon_{jc} \qquad (7)$$

In this regression equation, RDY_{jc} denotes R&D intensity of industry j of country c, which takes the value of the 1996-2000 average.[2] TCE_{jc} is the technology content of industry j of country c, which takes the 2001 value. This regression shows how well an industry's TCE in 2001 is explained by its 1996-2000 average R&D intensity.

[Table 2 about here]

Table 2 reports the regression results at five different values of θ. When θ = 0, the TCE index takes the value of PRODY, completely ignoring within-product quality differences. We find the R&D variable statistically significant in eight out of fourteen industries. This is not surprising since at the industry level the product mix of a more developed country tends to skew towards goods of high technology content, and hence even without considering within-product technology content differences, the aggregation to the industry level may still make PRODY highly correlated with R&D. If we had product-level R&D data, however, we would find zero correlation between PRODY and R&D since product-level PRODY is identical for all countries.

[Figure 1 about here]

It is worth pointing out that the value of θ ought to be non-zero. θ = 0 implies that the technology levels of the same good exported by different countries are identical, which is clearly at odds with data. For example, Figure 1 shows the relative unit values of "Men's shirts of cotton, knit" (HS10 = 6105100010). In 2001, there were 67 countries exporting this good to the U.S. Syria has the lowest Q of 0.28, while Australia has the highest Q of 6.32. Figure 1 shows that the relative unit values of the country-products are positively correlated with real GDP per capita levels of their exporting countries. The measure of PRODY (θ = 0) would miss entirely the technology content differences behind this positive correlation.

[2] R&D data for China and Chezk Republic are available only for 2001. For these two countries RDY_{jc} takes the value of R&D intensity in 2001.

Table 2 shows that the regression results are poor when θ = 1. The reason is that θ = 1 introduces excessive quality adjustment in the construction of TCE. Table 3 displays the size of quality multiplier Q^{θ} at different values of θ. When θ = 1, the product at the 1 percentile of Q distribution will have TCE=0.019×PRODY, while the product at the 99 percentiles of Q distribution will have TCE=38×PRODY. Such adjustments appear excessive and unwarranted.

[Table 3 about here]

Table 2 shows that the regression results are best when θ = 1/5. In ten of the fourteen industries the R&D variable is positive and statistically significant at the 10 percent level, and in another three industries the R&D variable is positive and statistically significant at the 15 percent level; the only one in which the R&D variable is not statistically significant is the natural-resource-intensive industry of "Coke, refined petroleum products and nuclear fuel". The regression results are slightly inferior when θ = 1/3 and θ = 1/10. Table 3 shows the size of quality multiplier. When θ = 1/5, the product at the 1 percentile of Q distribution will have TCE=0.45×PRODY, and the product at the 99 percentiles of Q distribution will have TCE=2×PRODY. Such adjustments appear reasonable and are probably on the conservative side. Accordingly we choose θ = 1/5 in our computation of TCE.

[Table 4 about here]

Table 4 reports the mediums of Q and TCE of China and World (93 countries). The medium value of China's product quality is 0.531 in 1989 and 0.553 in 2001, while the medium value of the TCE of Chinese products is 8,501, which increases to 11,205 in 2001. In comparison, the medium values of World's product quality are significantly higher, ranging from 0.933 in 1989 to 0.975 in 2001. The medium values of World's TCE are also higher, ranging from 11,634 in 1989 to 13,348 in 2001.

4. The Technology Content of China's Exports

In this section we use TCE indices to identify several features about the technology content of China's exports.

3.1. China's TCE at the Country Level

Recent studies by Rodrik (2006) and Schott (2006) raised the interesting question of whether China is an outlier in exporting goods that are more sophisticated than its development level implies. Table 5 gives our answer to this question. In the first three columns, we report results from the following regression:

$$\ln(EXPY_c) = \alpha_1 + \beta_1 \ln(RGDPL_c) + \gamma_1 \text{ CHINA} + \varepsilon_1$$

In this equation, $RGDPL_c$ is country c's real GDP per capita, CHINA is a dummy for China, and $EXPY_c$ is the average PRODY of country c's exports, a measured used by Rodrik (2006) for comparing the income content of China's exports with that of the other countries. The China dummy is found to be statistically significant at the 10 percent level from 1989 to 2000 (and at the 15 percent level in 2001), indicating that China is an outlier in terms of EXPY. This is a major argument of Rodrik (2006).

[Table 5 about here]

The last three columns of Table 5 report results from the following regression:

$$\ln(TCE_c) = \alpha_2 + \beta_2 \ln(RGDPL_c) + \gamma_2 \text{ CHINA} + \varepsilon_2$$

The results show that the China dummy is statistically significant at the 10 percent level from 1989 to 1993 and in 1995 (at the 15 percent level in 1994). After 1996, the China dummy remains positive but is statistically insignificant (at the 15 percent level in 1997). Thus, China disappeared to be an outlier after the mid 1990s. On average, the technology content of Chinese exports is compatible to China's development level, as illustrated in Figure 2. The difference between the results based on EXPY and those based on TEC highlights the importance of considering the product quality dimension in evaluating the technology content of China's exports. By ignoring China's low technology level that was behind the low quality of Chinese exports, Rodrik (2006) overestimated the technology sophistication of Chinese exports.

[Figure 2 about here]

Figure 3 depicts the TCE levels of the world and China, and the real GDP per capita level of China, over the sample period 1989-2001. During this period, China's real GDP per capita increased by 88 percent, while its TCE increased by 31 percent. In comparison, the world average TCE increased by 14 percent.[3] There are two observations about this graph. First, China's TCE is about half of the world's TCE, which is expected from comparative advantage theory. Second, China's TCE (averaged $7315 in the period) is much larger than its RGDPL (averaged $2777 in the period). One reason is that China's TCE in our study measures the technology content of China's manufacturing exports to the U.S., which presumably have higher technology content than China's non-manufacturing and/or non-tradable goods. Another possibility is that for the same product the varieties exported by Chinese firms may have higher technology content than the ones for domestic sale.

[Figure 3 about here]

To see if China upgraded its export structure over the period 1989-2001, we compute the ratio of China's TCE to the world's TCE. Figure 4 displays this ratio. The upward trend is clear. The technology content of Chinese exports is 0.474 of the world's TCE in 1989, and it increased to 0.564 in 2001, a growth of 17 percent.

[3] In our construction of TEC, we use RGDPL of every corresponding year. This allows TCE to change with RGDPL over time, so that TCE growth and RGDPL growth are comparable.

[Figure 4 about here]

How did China achieve the 17 percent growth in TCE? A complete answer to this question requires a careful analysis at the firm level, which we leave for future research. Here we take a look at the composition of Chinese exports. First we divide Chinese exports into "traditional goods" China exported in 1989 (and continued to export most of them), and "newly added goods" which China added to its exports in the period 1990-2001. There are 3,969 traditional goods, and the number of newly added goods is 3,819 in the period 1990-2001. Figure 5 shows the average TCE levels (weighted by export shares) of these two groups of goods. We notice that the newly added exports have a significantly higher TCE than the traditional exports, but the gap has narrowed over time. A useful observation is that China's traditional exports achieved significant growth in TCE from 1994 to 2001.

[Figure 5 about here]

Figure 6 provides further evidence about the composition of China's exports. Rather than dividing goods into traditional exports (exported only in 1989) and newly added exports (added in 1990-2001), we now compare the TCE levels of old exports (exported in the previous year) and new exports (newly added in the current year). Figure 6 reveals an interesting pattern. Before 1995, the goods China added to its export basket had higher TCE. From 1995 to 2000, however, the goods China added to its export basket had lower TCE.[4] This product-mix pattern on China's exports may constitute one of the reasons for our earlier finding that China was an TCE outlier in cross-country comparisons before 1995 but not after 1995 (Table 5).

[Figure 6 about here]

[4] In 2001 the TCE of China's new exports jumped up significantly because China added a few products with very high TCE, for example, "Sheet piling of iron or steel" (TCE=73,589). Unfortunately we do not have data for years after 2001 to see how the pattern evolved from 2001.

3.2. China's TCE at the Industry and Product Levels

We investigate further China's TCE at the industry and product levels. Table 6 reports regressions performed on fourteen manufacturing industries. The results indicate that in the majority of industries (ten out of fourteen) the TCE levels of Chinese exports are comparable to its development level. We find that in the first half of the 1990s, three industries had significantly higher TCE indices. They are "textiles, leather and footwear" industry (45 percent of China's manufacturing exports to the U.S., 1989-2001 average), "chemicals and chemical products" industry (2.6 percent), and "food, beverages and tobacco" industry (0.01 percent). In the second half of the 1990s, only two industries, chemicals and refined petroleum products, show a statistically significant China dummy in some years. The reasons for these industry-level patterns deserve further investigation.

[Table 6 about here]

Table 7 reports results from regressions at the product level. China's product-level TCEs are found to be incompatible to its development level from 1991 to 2001. China exported products whose technology content is significantly below countries at similar development levels. Moreover, the gap had been widening over time. In 1991, China's product-level TCE was 1.4 percent lower than that of a country at the same development level. In 2001, the gap became 8.7 percent. Since the TCE value of a product is determined by its relative quality (measured by relative unit value), this result is a mirror image of Schott's (2006) finding that Chinese exported goods carried large price discounts that had been increasing over time.

[Table 7 about here]

The previous examination has identified four features of China's TCE. First, China's overall TCE grew faster than the world average. Second, China's TCE was higher than its presumed level before the mid 1990s but was compatible to its development level afterward. Third, China added new products of relatively high TCE before the mid 1990s, but the new products added after the mid 1990s had relatively low TCE. Fourth, Chinese products had a quality level below the presumed level, and the quality gap was widening over time. For these four features to be consistent with each other, we need to find some positive driving force that has been sustaining the overall TCE growth of Chinese exports, especially after the mid 1990s.

We can search for such a driving force by decomposing China's TCE. The TCE value combines three effects. First is a quality effect, which is negative for China. Second is a product-mix effect of adding and dropping products in the export basket. This effect was positive for China before the mid 1990s but negative afterward. Third, there is an export-share effect that is contained in the weights. All else equal, if China increased the export shares of the goods with relatively high TCE, China's overall TCE would increase.

[Table 8 about here]

Table 8 provides evidence supporting this conjecture. At both the industry and product levels, we find a positive and statistically significant correlation between the growth rate of export share and the level of TCE. This result indicates that on average China had stronger export expansion in the goods whose TCE are relatively high. The reason for this is yet to be explored, but it is clear that without this positive export-share effect on TCE, China would have seen a decline in its overall TCE after the mid 1990s because of the negative quality effect and product-mix effect.

5. Summary and Conclusion

In this paper we construct a measure of technology content of exports (TCE) and apply it to China. This measure has an advantage over the existing ones in considering not only the technology content differences across products, but also the technology content differences across country-varieties within product. Such a measure is particularly useful for studying countries like China, whose product quality is considerably lower than the quality of the same product exported by other countries. Without considering the product quality dimension, one would overestimate the technology sophistication of China's exports.

Using the TCE indices computed from U.S. import data (HS10) and PWT6.1 data, we identify several features regarding the technology content of Chinese exports in the period 1989-2001. We find that before the mid 1990s China was an outlier in exporting a basket of goods whose average technology content is significantly higher than those exported by countries at the same development level. We find, however, that China was no longer an outlier after the mid 1990s. At the industry level, we find that China had higher TCE levels than its peer countries only in a few industries such as textiles and chemicals and mainly in the early 1990s. At the product level, we find that the TCE levels of Chinese products are significantly below their presumed levels due to low product quality; the quality gap had been widening over time.

We provide some empirical evidence that helps us understand the features of Chinese TCE. In the first half of the 1990s, we find that China added to its export basket new goods whose TCE levels were significantly higher than the current exports; this positive product-mix effect served to offset the negative quality effect. In the second half of the 1990s, however, we find that the product-mix effect turned negative----the goods China added to its export basket had TCE levels lower than the current exports. We find however that there was a positive export-share effect on China's overall TCE. Over the period 1989-2001, China on average expanded the export shares more in goods whose TCE levels are relatively high. This export-share effect must have played a crucial role in offsetting the negative quality effect and product-mix effect, thereby sustaining China's overall TEC on an upward trend.

Understanding the nature of China's exports is essential for understanding the Chinese growth miracle and the potential of China's future growth. This paper contributes to the literature by improving on the measurement of the technology sophistication of Chinese exports and identifying several characteristics related to it. Much work is needed to explore the reasons behind these identified characteristics. For example, what was the role of foreign direct investment in shaping the technology content of Chinese exports? Why did the Chinese exports have increasingly lower unit values compared with exports of the same goods by other countries? Answering these questions demands more data and more effort, but will provide valuable guidance for policy makers. We plan to explore these questions in our future research.

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Appendix

The trade data for this study are from Feenstra, Romalis and Schott (2002). This dataset contains information on U.S. merchandise imports disaggregated by Harmonized System to the 10-digit level (HS10), recorded by the U.S. Customs, from 1989 to 2001. We use the data on "general imports", which are imports as they come off the dock. We follow Schott (2004) to use the manufacturing subset of this dataset. Manufacturing goods correspond to Industry 5-8 in SITC1 classification. They are Chemicals (SITC1=5), Manufactured Materials (SITC1=6), Machinery (SITC1=7), and Miscellaneous Manufacturing (SITC8).

The HS10 data are distinguished by source country and include information on value and quantity. Data are also distinguished by a source country sub-code that describes the trade treatment received by the import (e.g., free-trade agreements, Generalized System of Preferences), and consequently a country may have multiple observations of exports of the same good recorded by the U.S. Customs. In such cases, we aggregate the value and quantity for a country for every HS10 product, thus obtaining unique pairs of value and quantity for every country-product observation. In 2001, there are 247,104 country-product observations, from which we obtain 226,583 unique country-product observations that show positive import value. Among these observations, there are 36,112 observations for which the quantity units could not be measured (the dataset shows positive import value but zero import quantity), which gives rises to a sample of 190,471 observations.

To construct our index of technology content of exports (TCE), we use real GDP per capita (RGDPL) from Penn World Table 6.1 (PWT6.1). PWT6.1 provides the data from 1989 to 2000. We compute the 2001 real GDP per capita data by using PWT6.1's 2000 RGDPL and the World Bank's 2001 annual percentage growth rate of GDP at market prices based on constant local currency. PWT6.1 has different numbers of countries in different years. We use the list of 168 countries in Table A of Data Appendix for PWT6.1. In five cases a single country code in the U.S. trade dataset corresponds to multiple PWT countries because the former contains several countries (see the table below). In these cases, we compute the real GDP per capita from the population and GDP data of the countries in the country group.

Country Code in U.S. Trade Dataset	Countries in PWT6.1
117100	Botswana, Lesotho, Namibia, Swaziland
162300	Ethiopia, Eritrea
166240	Cape Verde, Guinea-Bissau, Sao Tome and Principe
356580	Antigua, Dominica, Grenada, St. Kitts & Nevis, St. Lucia, St.Vincent & Grenadines
530560	Belgium, Luxembourg

We merge the U.S. trade data and the PWT6.1 data by unique country code. This leaves us 188,629 country-product observations in 2001, all of which have positive unit values. Dividing a country's unit value of a product by the export-share-weighted average unit value of the product of all its exporting countries, we obtain the relative unit value of the country in this product (denoted by Q).

Relative unit values of HS10 goods vary considerably across countries. Observing the data we find that the maximum and minimum values are implausible. For example, the minimum of relative unit values in 2001 is 0.00000001, and the maximum is 37,267. U.S. General Accounting Office (1995) had an analysis of eight commodities for 1992 in this dataset and found two underlying causes for the variations in unit values. "First, there were variations that resulted from commodity classifications so broad that the same code could cover products of different types, quality, and intended use…The second cause for the variations was errors—such as misclassifying the product or entering the wrong quantity or total value—made by the filer when entering data into Customs' Automated Commercial System" (pp. 1-2). We believe that the extremely small and large relative unit values are a result of the second reason mentioned above, i.e., errors in entering the data. To remove these erroneous values, we drop the top 1 percentile and bottom 1 percentile of the data in terms of relative unit values. Table A1 reports summary statistics before and after this adjustment. The adjustment effectively removes the implausible extreme values. The maximum and minimum values look much more plausible and are stable across years. The number of observations is 184,855 (152 countries) in 2001 after the adjustment.

To compute the index of technology content of exports (TCE) across years, it is important to use a consistent sample of countries to avoid possible omitted country bias (Hausmann, Hwang, and Rodrik, 2006, p. 8). For the sample period 1989-2001, there are 93 countries with data on RGDPL for every year (119 countries have RGDPL in 2001). Table A1 reports the summary statistics of relative unit values for this sample for the period 1989-2001, to which we apply in each year the adjustment of dropping two percent observations with extreme relative unit values.

Our study also uses industry-level R&D data of 18 OECD countries and China. The OECD R&D data are from SourceOECD Science and Technology Database, and the industry gross product data are from SourceOECD STAN Structural Analysis Database. OECD data are classified in ISIC (Rev. 3) manufacturing industries. The Chinese R&D and gross product data are from China's national surveys of firms, which are classified in Chinese SIC which is similar to ISIC. The R&D data are available for most countries when ISIC industries are grouped into 14 industries. We compute an industry's R&D intensity as the ratio of R&D spending to gross product (multiplied by 100). The U.S. import data are aggregated to the 1987 version import-based SIC industries. Table A2 provides the industry concordances we use.

Table A1. Relative Unit Values of HS10 Products

		Min	Max	SD	Medium	Obs
2001*	Original data	0.0000001	37267	128.64	0.960	188,629
	Adjusted data	0.008	87.26	6.93	0.960	184,855
2001	Original data	0.0000001	35072	123.60	0.975	165,117
	Adjusted data	0.008	84.17	6.70	0.975	161,814
2000	Original data	0.0000006	28514	128.79	0.977	166,193
	Adjusted data	0.008	81.19	6.44	0.977	162,869
1999	Original data	0.000002	46371	170.20	0.976	159,302
	Adjusted data	0.009	80.24	6.54	0.976	156,116
1998	Original data	0.000009	37871	128.00	0.965	157,100
	Adjusted data	0.008	89.37	7.03	0.965	153,958
1997	Original data	0.000001	29889	135.60	0.964	155,672
	Adjusted data	0.007	91.64	7.16	0.964	152,559
1996	Original data	0.00001	16329	114.44	0.968	147,355
	Adjusted data	0.009	80.14	6.41	0.968	144,409
1995	Original data	0.000005	19330	107.00	0.964	142,186
	Adjusted data	0.010	74.57	5.90	0.964	139,343
1994	Original data	0.0000009	13530	75.44	0.964	133,709
	Adjusted data	0.010	68.67	5.62	0.964	131,033
1993	Original data	0.000002	9953	63.80	0.954	125,200
	Adjusted data	0.009	70.00	5.54	0.954	122,785
1992	Original data	0.000007	8625	61.38	0.950	119,071
	Adjusted data	0.009	67.62	5.50	0.950	116,689
1991	Original data	0.0000002	9397.6	70.87	0.943	117,293
	Adjusted data	0.009	61.37	5.07	0.943	114,949
1990	Original data	0.000011	8497	62.98	0.932	116,141
	Adjusted data	0.010	57.13	4.79	0.932	113,819
1989	Original data	0.000009	9634	58.04	0.933	115,232
	Adjusted data	0.010	54.89	4.57	0.933	112,928

* The first sample for 2001 contains 119 countries that have unit value data in 2001. The remainder of the table is for a sample of 93 countries that have unit value data and real GDP per capita data available for all years in the period 1989-2001.

Table A2. Industry Concordances

ID	ISIC (Revision 3)	U.S. SIC (1987 version)	Chinese SIC (1994 version)
1	Food products, beverages and tobacco (15, 16)	20, 21	13, 14, 15, 16
2	Textiles, leather and footwear (17, 18, 19)	22, 23, 31	17, 18, 19
3	Wood, paper, printing, and publishing (20, 21, 22)	24, 26, 27	20, 22, 23
4	Coke, refined petroleum products and nuclear fuel (23)	29	25
5	Chemicals and chemical products (24)	28	26, 28
6	Rubber and plastics (25)	30	29, 30
7	Other non-metallic mineral products (26)	32	31
8	Basic metals (27)	33	32, 33
9	Fabricated metal products (28)	34	34
10	Machinery and equipment; Office, accounting and computing machinery (29, 30)	35	35, 36
11	Electrical machinery; radio, television and communication equipment (31, 32)	36	40, 41
12	Medical, precision and optical Instruments; watches and clocks (33)	38	27, 42
13	Transport equipment (34, 35)	37	37
14	Furniture; recycling; manufacturing n.e.c. (36, 37)	25, 39	21, 24, 43

Table 1: Real GDP Per Capita, China and the U.S.

	GDP Per Capita, World Bank (Constant 2000 $)			GDP Per Capita, PWT6.1 (PPP, Constant 1996 $)		
	China	U.S.	China/U.S.*100	China	U.S.	China/U.S.*100
1989	383	28,062	1.36	1,673	26,283	6.36
1990	392	28,263	1.39	1,790	26,470	6.76
1991	422	27,833	1.52	1,977	25,923	7.63
1992	476	28,366	1.68	2,204	26,501	8.32
1993	536	28,747	1.87	2,455	26,965	9.11
1994	600	29,550	2.03	2,645	27,879	9.49
1995	658	29,942	2.20	2,818	28,410	9.92
1996	716	30,704	2.33	2,969	29,194	10.17
1997	775	31,716	2.44	3,110	30,190	10.30
1998	827	32,671	2.53	3,276	31,092	10.54
1999	882	33,748	2.61	3,415	32,133	10.63
2000	949	34,599	2.74	3,747	33,308	11.25

Table 2: Regressions on R&D Intensity, Different Degrees of Quality Adjustment

Industries (ISIC Codes)	θ=0	θ=$\frac{1}{10}$	θ=$\frac{1}{5}$	θ=$\frac{1}{3}$	θ=1
Food products, beverages and tobacco (15, 16)	0.037 (0.033) R^2=0.068	0.065** (0.023) R^2=0.316	0.094** (0.038) R^2=0.266	0.133* (0.067) R^2=0.190	0.301+ (0.175) R^2=0.147
Textiles, leather and footwear (17, 18, 19)	0.199*** (0.056) R^2=0.424	0.202*** (0.057) R^2=0.423	0.204*** (0.058) R^2=0.415	0.206*** (0.062) R^2=0.392	0.203* (0.111) R^2=0.165
Wood, paper, printing, and publishing (20, 21, 22)	0.078** (0.030) R^2=0.284	0.082** (0.030) R^2=0.297	0.084** (0.031) R^2=0.298	0.087** (0.033) R^2=0.283	0.089 (0.070) R^2=0.087
Coke, refined petroleum products and nuclear fuel (23)	0.021 (0.248) R^2=0.0005	0.0026 (0.24) R^2=0.00	－0.158 (0.233) R^2=0.0003	－0.041 (0.228) R^2=0.002	－0.165 (0.289) R^2=0.023
Chemicals and chemical products (24)	0.099** (0.045) R^2=0.234	0.104** (0.047) R^2=0.218	0.108** (0.049) R^2=0.232	0.114** (0.054) R^2=0.218	0.134 (0.087) R^2=0.129
Rubber and plastics (25)	0.134** (0.061) R^2=0.222	0.148** (0.063) R^2=0.244	0.163** (0.067) R^2=0.261	0.183** (0.072) R^2=0.274	0.302** (0.125) R^2=0.256
Other non-metallic mineral products (26)	0.146*** (0.028) R^2=0.615	0.159*** (0.031) R^2=0.609	0.174*** (0.035) R^2=0.588	0.194*** (0.042) R^2=0.554	0.323*** (0.092) R^2=0.422
Basic metals (27)	0.123 (0.077) R^2=0.139	0.128* (0.072) R^2=0.164	0.133* (0.069) R^2=0.190	0.140** (0.067) R^2=0.215	0.136 (0.126) R^2=0.067
Fabricated metal products (28)	0.090*** (0.028) R^2=0.393	0.123*** (0.034) R^2=0.443	0.156*** (0.043) R^2=0.452	0.201*** (0.056) R^2=0.443	0.451*** (0.148) R^2=0.368
Machinery and equipment; Office, accounting and computing machinery (29, 30)	0.259*** (0.059) R^2=0.533	0.273*** (0.060) R^2=0.548	0.285*** (0.064) R^2=0.536	0.294*** (0.074) R^2=0.483	0.270 (0.188) R^2=0.108
Electrical machinery; radio, television and communication equipment (31, 32)	0.099 (0.063) R^2=0.134	0.117+ (0.071) R^2=0.144	0.135+ (0.081) R^2=0.149	0.161+ (0.096) R^2=0.149	0.337+ (0.220) R^2=0.128
Medical, precision and optical Instruments; watches and clocks (33)	0.073 (0.057) R^2=0.098	0.094 (0.064) R^2=0.124	0.111+ (0.072) R^2=0.136	0.133+ (0.085) R^2=0.14	0.236 (0.166) R^2=0.119
Transport equipment (34, 35)	0.180* (0.091) R^2=0.187	0.198* (0.101) R^2=0.183	0.209* (0.111) R^2=0.172	0.216* (0.124) R^2=0.152	0.101 (0.198) R^2=0.015
Furniture; recycling; manufacturing n.e.c. (36, 37)	0.078 (0.057) R^2=0.133	0.098 (0.069) R^2=0.146	0.123+ (0.080) R^2=0.164	0.163+ (0.095) R^2=0.197	0.442*** (0.155) R^2=0.405

Note: ***, **, *, + indicate statistical significance at the 1, 5, 10, and 15 percent levels, respectively.

Table 3: Quality Multipliers, 2001

Distribution of Q	Q	$Q^{1/3}$	$Q^{1/5}$	$Q^{1/10}$
Minimum	0.008	0.200	0.381	0.617
1 percentile	0.019	0.267	0.453	0.673
5 percentiles	0.081	0.433	0.605	0.778
10 percentiles	0.171	0.555	0.702	0.838
25 percentiles	0.465	0.775	0.858	0.926
50 percentiles	0.960	0.986	0.992	0.996
75 percentiles	2.016	1.263	1.151	1.073
90 percentiles	5.144	1.726	1.388	1.178
95 percentiles	10.122	2.163	1.589	1.260
99 percentiles	38.464	3.376	2.075	1.440
Maximum	87.257	4.435	2.444	1.563

Table 4: Mediums of Q and TCE, China and World

	China			World		
	Q	TCE	Obs	Q	TCE	Obs
1989	0.531	8,501	3,969	0.933	11,634	112,928
1990	0.515	8,561	4,215	0.932	11,832	113,819
1991	0.509	8,794	4,413	0.943	11,895	114,949
1992	0.520	8,885	4,755	0.950	11,960	116,689
1993	0.532	9,060	5,066	0.954	11,806	122,785
1994	0.541	9,553	5,407	0.964	12,276	131,033
1995	0.525	9,957	5,822	0.964	12,619	139,343
1996	0.540	10,167	6,144	0.968	12,743	144,409
1997	0.529	10,339	6,674	0.964	12,919	152,559
1998	0.539	10,537	6,939	0.965	13,016	153,958
1999	0.544	10,682	7,274	0.976	13,086	156,116
2000	0.553	11,144	7,741	0.977	13,285	162,869
2001	0.553	11,208	7,788	0.975	13,365	161,814

Notes: "World" contains 93 countries. "Obs" is the number of country-product observations.

Table 5: Regressions on RGDPL and a China Dummy, Country Level

	EXPY			TCE		
	RGDPL	CHINA	R^2	RGDPL	CHINA	R^2
1989	0.582***	0.751**	0.815	0.584***	0.664**	0.811
1990	0.587***	0.706***	0.864	0.599***	0.634**	0.872
1991	0.598***	0.687***	0.867	0.615***	0.610**	0.867
1992	0.591***	0.609**	0.840	0.599***	0.527**	0.846
1993	0.595***	0.602**	0.869	0.610***	0.524*	0.874
1994	0.576***	0.498*	0.859	0.586***	0.411^{+}	0.862
1995	0.575***	0.545**	0.882	0.586***	0.453*	0.886
1996	0.580***	0.508*	0.849	0.571***	0.391	0.808
1997	0.579***	0.520*	0.863	0.582***	0.420^{+}	0.869
1998	0.591***	0.491*	0.862	0.583***	0.374	0.873
1999	0.604***	0.520*	0.851	0.603***	0.401	0.849
2000	0.586***	0.497*	0.869	0.597***	0.391	0.875
2001	0.604***	0.489^{+}	0.845	0.611***	0.377	0.838

Notes: The regression equation is $\ln(X_c) = \alpha + \beta\ln(RGDPL_c) + \gamma CHINA + \varepsilon$, where variable X is TCE or EXPY, and CHINA is a dummy variable for China. The number of countries is 93 in all regressions. ***, **, *, + indicate statistical significance at the 1, 5, 10, and 15 percent levels. Standard errors are not reported to save space.

Table 6: Regressions on RGDPL and a China Dummy, Industry Level

ISIC Industries (Codes)	The China Dummy Is Positive and Significant	The China Dummy Is Insignificant
Food products, beverages and tobacco (15, 16)	1990*, 1991***, 1993-1994*	1989, 1992, 1995-2001
Textiles, leather and footwear (17, 18, 19)	1990**, 1991**, 1993*	1989, 1992, 1994-2001
Wood, paper, printing, and publishing (20, 21, 22)		1989-2001
Coke, refined petroleum products, nuclear fuel (23)	1998*, 2000***, 2001**	1990, 1993-1997, 1999
Chemicals and chemical products (24)	1989-1992**, 1993-1994*, 1996**, 1997*, 1998**	1995, 1999-2001
Rubber and plastics (25)		1989-2001
Other non-metallic mineral products (26)		1989-2001
Basic metals (27)		1989-2001
Fabricated metal products (28)		1989-2001
Machinery and equipment; Office, accounting and computing machinery (29, 30)		1989-2001
Electrical machinery; radio, television and communication equipment (31, 32)		1989-2001
Medical, precision and optical Instruments; watches and clocks (33)		1989-2001
Transport equipment (34, 35)		1989-2001
Furniture; recycling; manufacturing n.e.c. (36, 37)		1989-2001

Notes: The regression equation is $\ln(TCE_{jc}) = \alpha_j + \beta_j \ln(RGDPL_c) + \gamma_j CHINA + \varepsilon$, where CHINA is a dummy variable for China. ***, **, * indicate statistical significance at the 1, 5, and 10 percent levels, respectively. China's "coke, refined petroleum products, nuclear fuel" industry had no exports to the U.S. in 1989, 1991, and 1992. The estimated β_j's (not reported here to save space) are positive and statistically significant in all regressions.

Table 7: Regressions on RGDPL and a China Dummy, Product Level

	ln (RGDPL)	CHINA	R^2
1989	0.087***	0.004	0.880
1990	0.094***	–0.001	0.882
1991	0.094***	–0.014***	0.881
1992	0.095***	–0.027***	0.882
1993	0.091***	–0.041***	0.883
1994	0.087***	–0.050***	0.880
1995	0.089***	–0.053***	0.873
1996	0.090***	–0.054***	0.867
1997	0.084***	–0.066***	0.866
1998	0.085***	–0.066***	0.866
1999	0.084***	–0.067***	0.868
2000	0.076***	–0.080***	0.877
2001	0.077***	–0.087***	0.871

Notes: The dependent variable is ln (TCE) at the HS10 level. All regressions include product-specific (HS10) fixed effects.

Table 8: China's Export-Share Growth and TCE Level, 1989-2001

	Correlation between Export-Share Growth and TCE Level	Observations
Industry level	0.607** (0.021)	14
Product level	0.398*** (0.000)	2,526

Note: The correlation uses export shares as weights.

Figure 1: Quality Index of "Men's Shirts of Cotton, Knit", 2001

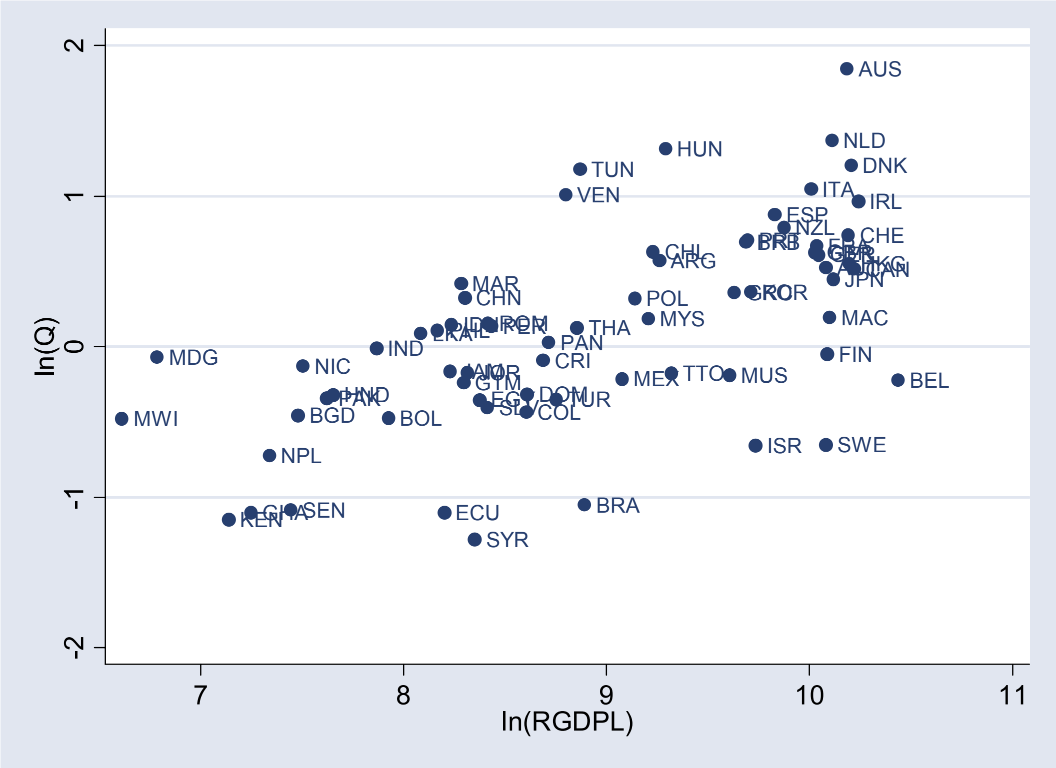

Figure 2: TCE Index and RGDPL, 2001

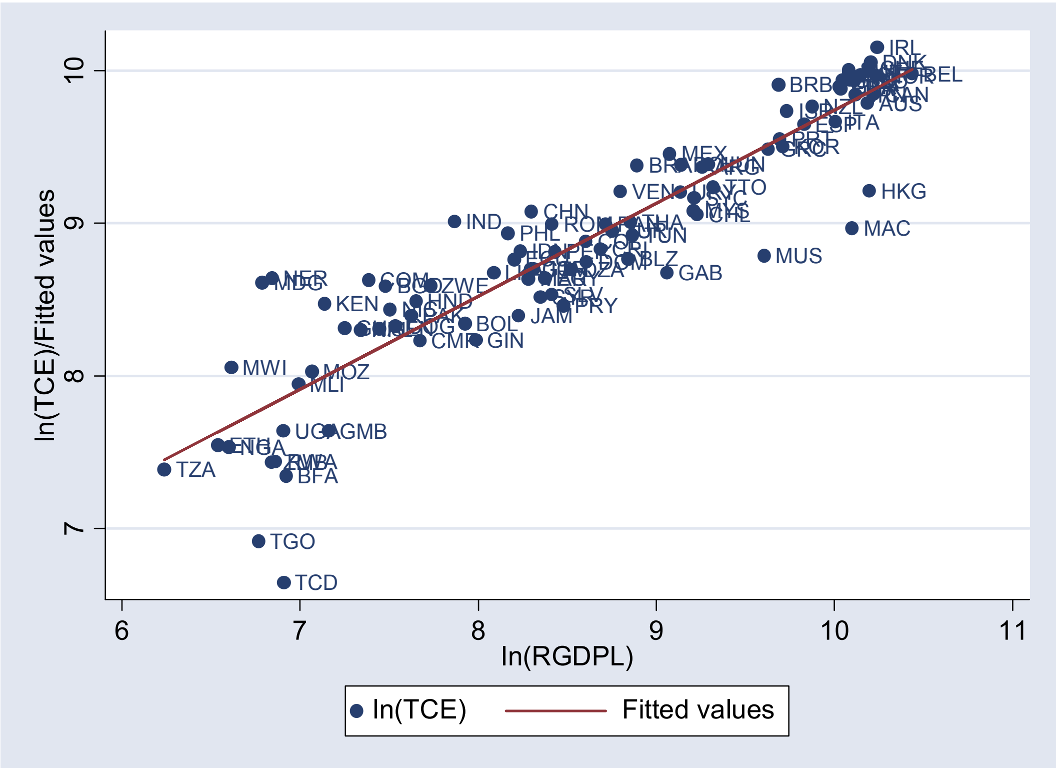

Figure 3: World's TCE, China's TCE, and China's RGDPL

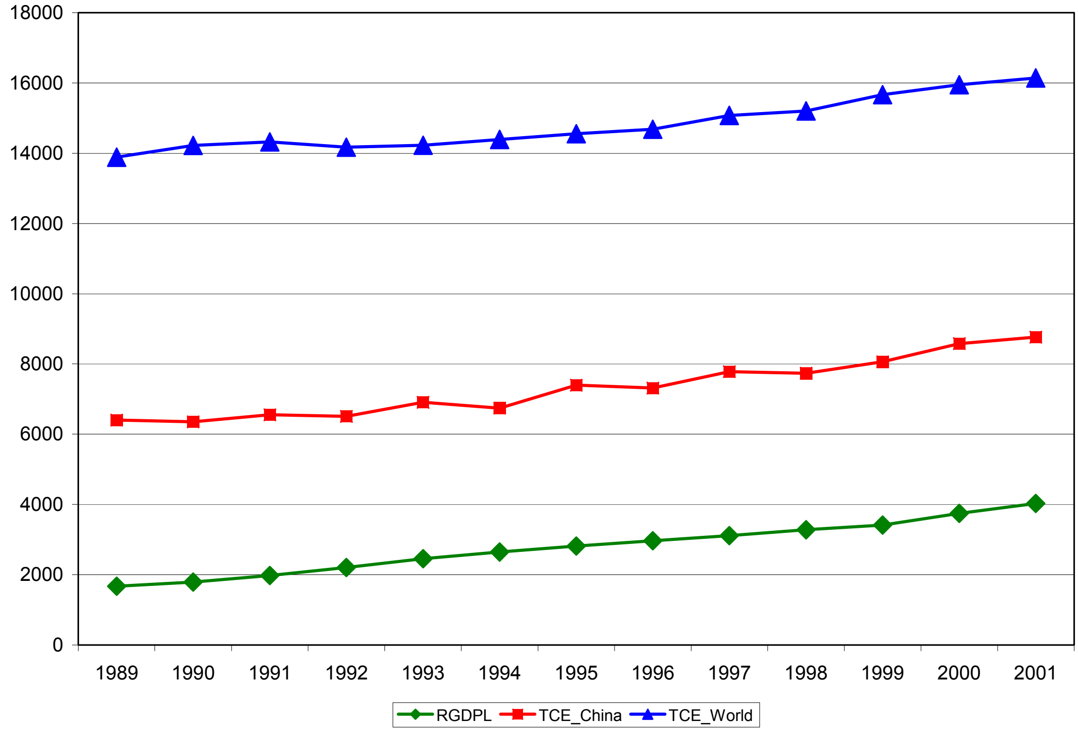

Figure 4: Ratio of China's TCE to World's TCE

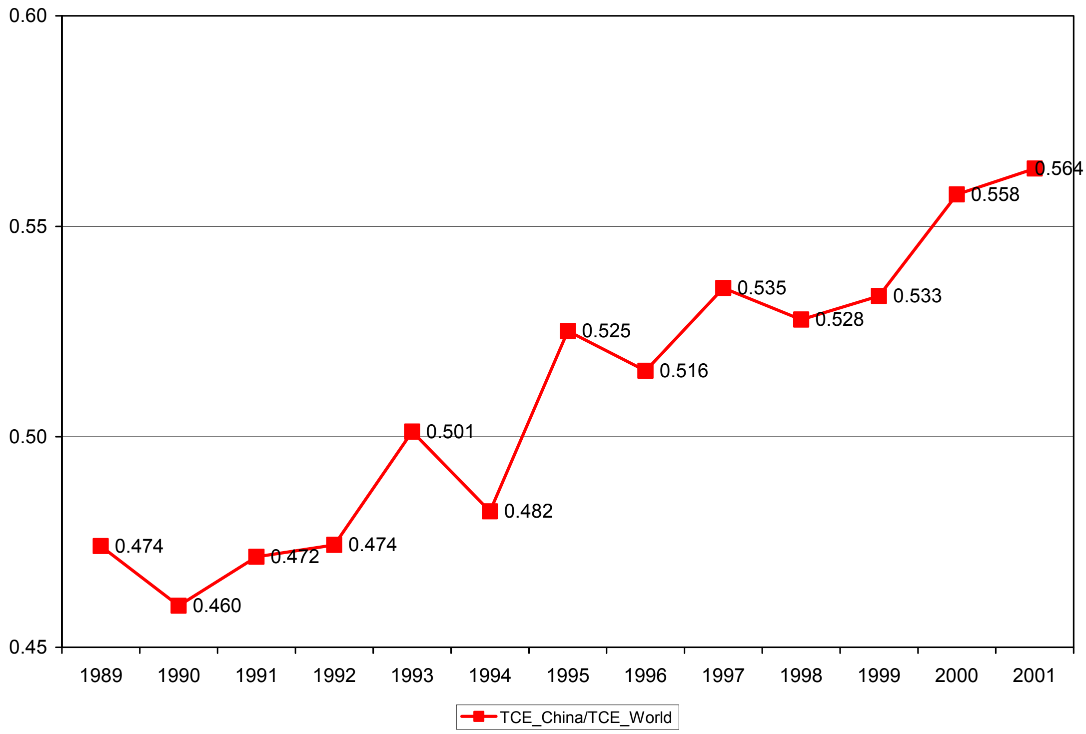

Figure 5: TCE of China's Traditional and Newly Added Exports

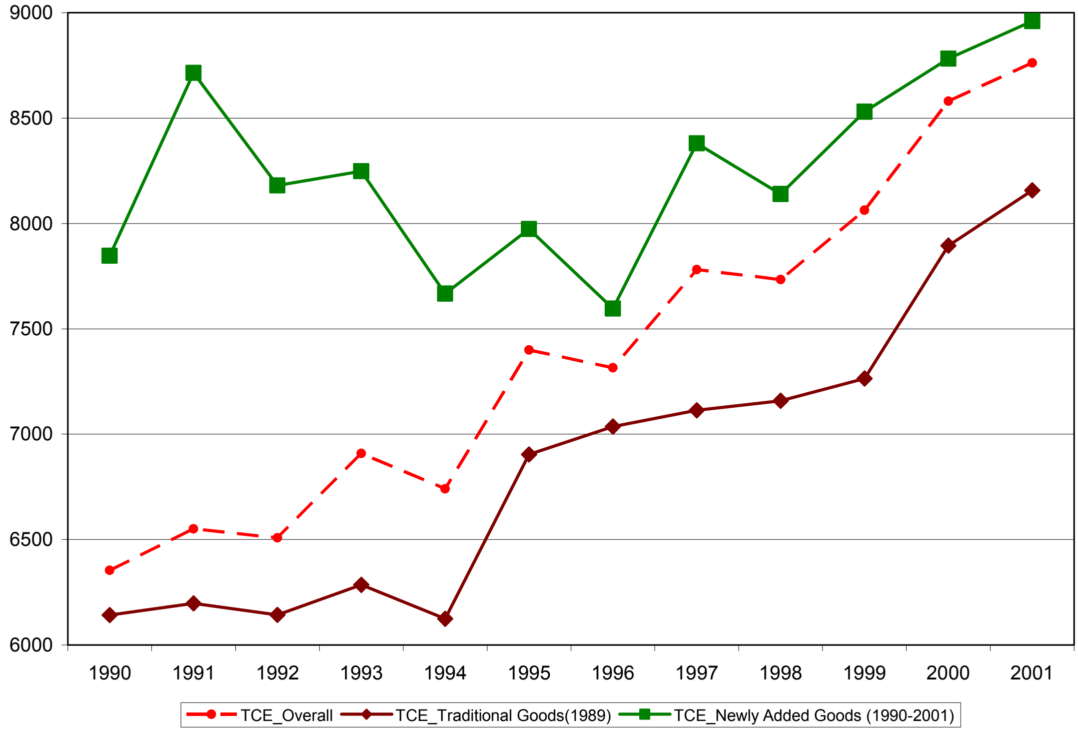

Figure 6: TCE of China's Old and New Exports, Yearly, 1990-2001