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Foreign direct investment, processing trade, and the sophistication of China's exports[☆]

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ABSTRACT

China's export structure has shown a rapid shift towards more sophisticated industries. While some believe that this trend is a result of processing trade and foreign direct investment, the evidence is mixed. This paper examines variations in level of export sophistication across China's manufacturing industries. We find that an industry's level of export sophistication is positively related to the share of wholly foreign owned enterprises from OECD countries and the share of processing exports of foreign-invested enterprises, and negatively related to the share of processing exports of indigenous Chinese enterprises. Evidence from the relative export prices of Chinese goods, which measure within-product export sophistication, shows a similar pattern.

1. Introduction

China's export structure has shown a rapid shift from labor-intensive industries to capital- and skill-intensive industries.[1] As China builds up its technological capacity and skilled labor force, its exports are expected to be increasingly sophisticated. However, studies find that the level of sophistication of China's exports is already exceptionally high. Rodrik (2006) illustrates a cross-country relationship between the sophistication level of exports and the per capita income; he 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" (pp. 3–4). Schott (2008) measures the overlap of a country's exported products with that of OECD countries using the export similarity index (ESI) of Finger and Kreinin (1979); he finds that "China's overlap with the OECD across products is substantial and increasing over time" (p. 9).

Why is China's export sophistication level so exceptionally high? Some believe that it is due to the size and nature of China's processing trade. Processing exports are significant to China's foreign trade, accounting for 55% of China's exports to the world in

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[1] In 1992, more than half of China's manufacturing exports to the U.S. were from "Textiles, apparel, leather and footwear"; this share fell to less than one quarter in 2005. By contrast, "Machinery and equipment; office, accounting and computing machinery" accounted for only 7% in 1992, and its share rose to 26% in 2005. "Electrical machinery; radio, television and communication equipment" accounted for 12% in 1992, and its share rose to 24% in 2005. These two more sophisticated industries now account for half of China's manufacturing exports to the U.S. market (Xu, 2007, Table 1).

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2005 (Ferrantino et al., 2007, p. 10). Moreover, processing exports of Advanced Technology Products (ATP) accounted for more than 92% of China's total ATP exports every year since 1996, and over 95.5% every year since 2002 (Ferrantino et al., 2007, p. 37). Branstetter and Lardy (2006, p. 38) pointed out that "China is able to export huge quantities of electronic and information technology products only because it imports most of the high value-added parts and components that go into these goods." Using production data rather than export data, Van Assche and Gangnes (2008) constructed a product-sophistication index similar to Rodrik's (2006) and argued that their measure is less subject to the influence of processing trade. Applying this measure, they found no evidence that China's electronics *production* activities are exceptionally sophisticated, which implies that Rodrik's (2006) finding of an exceptionally high level of export sophistication in China may be a result of the high sophistication of China's imported parts and components in the processing trade. In a recent study of the characteristics of China's exports, Amiti and Freund (forthcoming) showed evidence of a significant skill upgrade in China's total exports from 1992 to 2005, but no evidence of a skill upgrade after excluding processing exports from total exports.

Foreign direct investment (FDI) is believed to be another important reason for China's exceptionally high level of export sophistication. Exports by foreign invested enterprises (FIEs) accounted for more than half of China's exports since 2001, and more than 85% of China's ATP exports every year since 2003 (Ferrantino et al., 2007, p. 40).[2] The FDI explanation is reinforced by the role of FIEs in China's processing exports, especially in high-tech processing exports. Branstetter and Lardy (2006, p. 39) pointed out that "most exports of electronic and information products are assembled not by Chinese owned firms but by foreign firms that are using China as an export platform."

Given the strong arguments discussed above, it is important to estimate how significant a role processing trade and FDI play in determining the level of sophistication of China's exports. If they play a major role, then China's exceptionally high level of export sophistication may not imply that China has developed its own technological capacity for producing the highly sophisticated goods that would enable it to compete directly with advanced countries. On the other hand, if they are not major determinants of China's high level of export sophistication, then we need to find out what makes China so special in having the exceptionally high sophistication of exports documented by Rodrik (2006) and Schott (2008). For China's policy makers, it is important to know if domestic human capital has played a positive role in China's rising export sophistication, and if government policies towards FDI and processing trade have promoted the upgrade of China's export structure in ways benefitting China. Thus, research on the determinants of the sophistication of China's exports is of both academic and policy value.

In a recent study, Wang and Wei (forthcoming) investigated the determinants of China's export sophistication level by examining its variations across different cities in China.[3] Surprisingly, they found that neither processing trade nor FDI seem to have played an important role in raising China's export sophistication. Instead, they found that improvements in human capital and government policies in the form of tax-favored high-tech zones have been key determinants of China's rising export sophistication.

One reason for Wang and Wei's (forthcoming) surprising finding on the role of FDI may be that they did not distinguish between the FDI from more technologically advanced OECD countries and the FDI from less technologically advanced sources such as Hong Kong, Macao or Taiwan. Without such a distinction, an aggregate measure of FDI may prevent its positive effect on the level of sophistication of exports from being identified. In their assessment of the role of processing trade, Wang and Wei (forthcoming) found that the estimated effect of processing exports on the sophistication level of a Chinese city's exports is actually *negative* for exports produced outside policy zones. Additionally, they found that although the estimated effect of processing exports is positive for exports produced inside policy zones, it is smaller than that of non-processing exports. Wang and Wei (forthcoming) did not distinguish processing exports of foreign firms from those of indigenous Chinese firms. Such a distinction is important as the positive contribution of processing trade to China's rising level of export sophistication is often associated with the processing trade activities of multinational enterprises.[4]

In this paper, we carry out an industry-level analysis that examines variations in level of export sophistication across China's manufacturing industries. In contrast to Wang and Wei's (forthcoming) city-level study which provides an in-depth analysis of the variations in FDI and processing trade across Chinese regions, our industry-level study allows an in-depth analysis of industry variations. Thus the two studies are complementary. Moreover, our data distinguishes between FIEs funded by Hong Kong, Macao and Taiwan (HMT) and those funded by non-HMT (mainly OECD) countries, as well as between processing exports of FIEs and those of indigenous Chinese firms. This allows us to estimate the effects of the distinctive parts of FDI and processing trade, which generates new results contributing to the literature.

To preview our results, we find that *overall* FDI and processing trade have no statistically significant effects on the sophistication of China's exports, which is in line with Wang and Wei (forthcoming). However, once FDI and processing trade are broken down into distinctive parts, two results emerge. First, the presence of wholly foreign owned enterprises (WFOEs) from OECD countries positively affects the export sophistication level of Chinese industries, while the presence of other types of foreign firms has no effect. Second, the export sophistication level of a Chinese industry depends positively on the share of processing exports of FIEs in the industry, and negatively on the share of processing exports of indigenous firms in the industry. Thus, the evidence from our study highlights the importance of dividing FDI and processing trade into different categories in identifying their impacts on the sophistication of China's exports.

[2] Gilboy (2004, p. 39) reports data that shows the dominance of FIEs in China's advanced industrial exports.

[3] Wang and Wei (forthcoming) adopted an export dissimilarity index (EDI) to measure sophistication of China's export structure. They showed that EDI is algebraically equivalent to ESI, which was used by Schott (2008), but the use of EDI (in logarithm) yields better results in their regression analysis.

[4] Koopman, Wang, and Wei (2008) find that FIEs tend to have higher foreign content in their exports than do indigenous Chinese firms.

Like Wang and Wei (forthcoming), we also perform an analysis of unit values of exports to examine variations of export sophistication *within* the same product category. Schott (2008) observed that while China's product-mix overlap with the OECD is substantial and increasing over time, China's export prices (unit values) are "consistently lower than the prices of countries at a similar level of development, and this disparity increases over time in most industries" (pp. 9–10).[5] Using the relative unit value of a Chinese industry's exports as measure of within-product export sophistication, we find that the measure is positively related to the share of WFOEs from OECD countries and the share of processing exports of FIEs, and negatively related to the share of processing exports of indigenous Chinese enterprises. Thus our results from within-product export sophistication are consistent with those from across-product export sophistication.

The remainder of the paper is organized as follows. Section 2 defines measures of export sophistication and displays some characteristics of the sophistication of China's exports. Section 3 discusses several theoretical hypotheses on determinants of the sophistication of China's exports. Section 4 describes data and empirical specifications. Section 5 reports empirical results and provides interpretation. Section 6 concludes. An Appendix contains the detail of data sources and variable construction.

2. Measures of export sophistication

Exported products differ in technological sophistication. Ideally one would like to compute the R&D content of an exported product as a measure of its sophistication level, but product-level R&D data is rarely available. Recently a number of researchers have constructed measures of export sophistication that do not require the use of product-level R&D data (Hausmann, Hwang, & Rodrik, 2007; Lall, Weiss, & Zhang, 2006; Rodrik, 2006; Schott, 2008; Wang & Wei, forthcoming). In this paper we adopt Rodrik's (2006) method of measuring the product sophistication level of good *i* with the following formula:[6]

$$\mathrm{PRODY}_i = \sum_{c \in C_i} \left\{ \frac{s_{ic}}{\sum_{j \in C_i} s_{ij}} Y_c \right\} \tag{1}$$

In this equation, PRODY_i denotes the product sophistication level of good *i* and is measured as the weighted average of the real GDP per capita (Y_c) of all countries in set C_i that export good *i*. The weight variable is $s_{ic}/\sum s_{ij}$, where s_{ic} is the share of good *i* in country *c*'s total export value, which reflects the importance of good *i* in country *c*'s export structure. Dividing s_{ic} by $\sum s_{ij}$ makes the sum of weights equal to one, so the weight variable reflects the importance of good *i* in country *c*'s exports *relative to* all the other countries that export the good. Thus, PRODY_i associates the sophistication level of a good with the income levels of the countries exporting it; a good exported intensively by high-income countries is considered to have high sophistication, and a good exported intensively by low-income countries is considered to have low sophistication.

One useful property of this PRODY index is that it can be aggregated to industry and country levels. Let *N* be the set of goods exported by industry *n* of country *c*. We can obtain the export sophistication level of industry *n* of country *c* from

$$\mathrm{PRODY}_{nc} = \sum_{i \in N} s_{inc} \;\; \mathrm{PRODY}_i \tag{2}$$

where s_{inc} is the export share of good *i* in industry *n* of country *c*. Eq. (2) shows that an industry's export sophistication level is the weighted average of the sophistication levels of all goods exported by the industry. Similarly, we define a country's export sophistication level as the weighted average of the sophistication levels of all goods exported by the country. Let *M* be the set of goods exported by country *c*. We obtain the overall level of export sophistication of country *c* from:[7]

$$\mathrm{EXPY}_c = \sum_{i \in M} s_{ic} \;\; \mathrm{PRODY}_i \tag{3}$$

where s_{ic} is the export share of good *i* in country *c*.

Fig. 1 shows China's EXPY relative to EXPY of OECD countries based on exports to the United States.[8] In 1992, China's EXPY was 7763; 44% of the average EXPY of the OECD. In 2005, China's EXPY rose to 12,566; 59% of the average EXPY of the world. The upward trend in Fig. 1 implies that the sophistication level of China's export structure is quickly catching up that of advanced countries.

[5] Xu (2007) shows that China's overall export sophistication would be consistent with the income level of its exporting regions if the measurement of China's overall export sophistication takes into account the relatively low sophistication level of product varieties of Chinese exports.

[6] PRODY is the original notation used by Rodrik (2006), as it measures a product's (PROD) content of per capita income (*Y*). This measure is similar to an earlier measure developed by Michaely (1984).

[7] EXPY is the original notation of Rodrik (2006) for overall export sophistication level of a country.

[8] Our computation covers 22 OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, Germany, France, Greece, Iceland, Ireland, Italy, Luxembourg, Japan, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom.

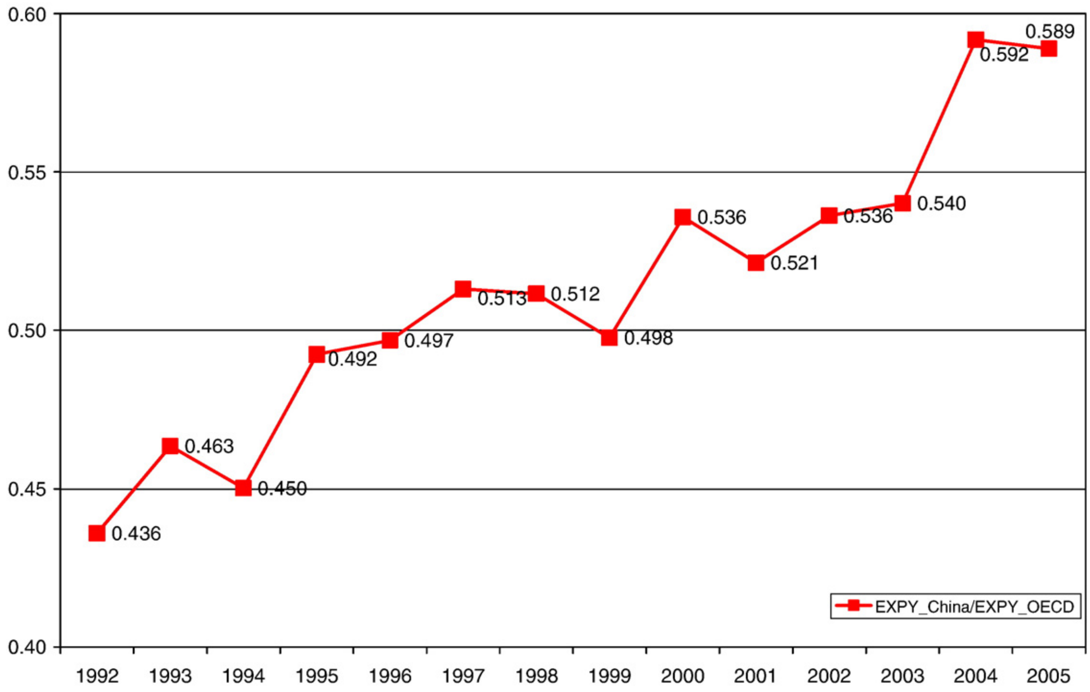

Fig. 1. Relative sophistication (EXPY) of Chinese exports, 1992–2005.

While China's export structure is upgrading rapidly, Chinese exports are observed to have significantly lower unit values or prices than those of other countries for a given product (Schott, 2008).[9] One interpretation of this observation is that low export prices signal the low quality of Chinese export varieties within a given product category. Schott (2008) terms it "within-product sophistication" to distinguish it from sophistication of export structure, which he terms "across-product sophistication".

To detect the underlying reasons of China's export sophistication, it is useful to examine both across-product and within-product export sophistication.[10] We need to be cautious, however, in interpreting export prices as signals of export quality.[11] For our study, we define the following relative-price index:

$$\mathrm{PRICE}_{ic} = \frac{u_{ic}}{\sum_d \left\{ \frac{x_{id}}{\sum_k x_{ik}} u_{id} \right\}} \tag{4}$$

In Eq. (4), u_{ic} denotes unit value of good i exported by country c. The denominator is a weighted average of the unit values for good i exported by all countries; the weight is a country's share in the total value exports of good i, thus reflecting the relative importance of the country in exporting good i. From the relative prices of all goods exported by industry n of country c, we obtain the relative price of the industry's exports as

$$\mathrm{PRICE}_{nc} = \sum_{i \in N} s_{inc} \;\; \mathrm{PRICE}_i \tag{5}$$

Similarly, we obtain the relative price of country c's exports as

$$\mathrm{PRICE}_c = \sum_{i \in M} s_{ic} \;\; \mathrm{PRICE}_i \tag{6}$$

[9] Schott (2004) documents that at the detailed HS10 level (e.g. men's cotton shirt), unit values of the same good in the U.S. market differ considerably across its exporting countries.

[10] Wang and Wei (forthcoming) examined both within-product sophistication (measured by EDI) and across-product sophistication (measured by unit values) of exports by Chinese cities.

[11] See Schott (2008) for a discussion of this issue.

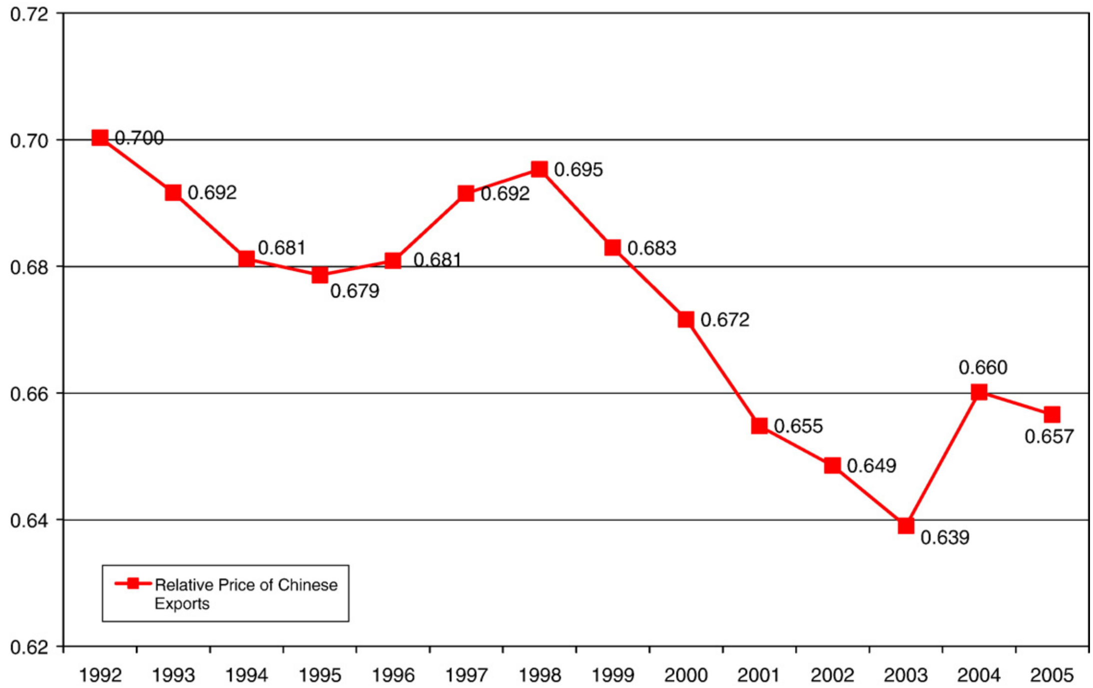

Fig. 2. Relative price (PRICE) of Chinese exports, 1992–2005.

Fig. 2 shows a downward trend in China's PRICE. Across a given basket, the price of China's export basket has been declining relative to the world's basket. In 1992, China sold its export basket at 70% of the world's price; in 2005, China sold its export basket at 66% of the world's price.

3. Theoretical hypotheses

In this section, we discuss several theoretical hypotheses that help to explain variations in level of export sophistication across Chinese industries. We first consider the role of human capital. In a Heckscher–Ohlin model of multiple goods, theoretical ambiguities notwithstanding, the export sophistication level of an industry (which is the weighted average of the sophistication levels of all export goods in the industry) is expected to be positively associated with its human capital level.[12] An industry with a higher (lower) level of human capital tends to have its product mix and output share biased towards more (less) sophisticated goods. This leads to the following hypothesis:

Hypothesis 1. The export sophistication level of an industry depends positively on the human capital base of the industry.

Next we consider the role of FIEs. It is argued that FIEs are at an inherent disadvantage compared to indigenous firms owing to communication costs, language and culture barriers, familiarity with local environments, and so on. As a result, FIEs must possess certain compensating advantages over local firms in order to compete in the host-country market (Dunning, 1993).

China's FDI comes from two distinctive sources: Hong Kong, Macao and Taiwan (HMT) and non-HMT (mainly OECD) countries. FIEs from OECD countries generally have superior technology as their source of competitiveness. By contrast, HMT firms are more familiar with the Chinese business environment and are therefore more advantaged in their local operations than OECD firms, which implies that the technology level needed for them to be competitive in the Chinese market is lower than that of OECD firms. It is well documented that HMT firms are less technology-intensive but better connected than OECD firms. For example, Luo (1999) presented survey data of 178 foreign firms in China and found that Asian (mainly HMT) firms are inferior in technological and organizational competencies than their Western counterparts but are superior in host country-specific knowledge such as marketing tactics and environmental familiarity.[13]

The FDI literature also suggests that ownership structure is a key determinant of the level of technology chosen by FIEs. According to the ownership-location-internalization (OLI) paradigm, WFOEs have the advantage of internalizing superior

[12] Consider a small open economy in the Heckscher–Ohlin model. The country's relative factor abundance determines the mix of the goods it exports. Suppose these goods belong to different industries. According to Rybczynski Theorem, the industry of higher average skill intensity will have its output shares biased towards more skill-intensive goods, and hence its export sophistication level tends to be higher.

[13] Studies of technology spillover effects provide further evidence consistent with the hypothesis that non-HMT firms possess higher levels of technology than HMT firms. Buckley, Clegg, and Wang (2002) call the two types of MNEs in China by the names of OC (overseas Chinese) and NC (non-Chinese); they find that NC firms generated both technological and international market access spillover benefits for indigenous Chinese firms, while OC firms conferred only market access benefits. Wei and Liu (2006) find evidence that non-HMT firms played a much greater role in inter-industry productivity spillovers than HMT firms.

technology within the firm. By contrast, joint ventures (JVs) rely more on the relationship with local partners to gain competitiveness in the local market. Javorcik and Saggi (2004) built a model of entry mode choice, which identifies a trade-off between securing a better position in the product market and allowing local partners to share profits. Their model predicts that foreign investors with more sophisticated technologies will prefer WFOEs to JVs. Most empirical evidence (Caves, 1996, Section 3.4) confirms that WFOEs tend to adopt higher-level technologies than JVs.[14]

The above discussion establishes the following hypothesis.

Hypothesis 2. The export sophistication level of a Chinese industry depends positively on the presence of wholly foreign owned enterprises from OECD countries in the industry.

Next we consider the role of processing trade. As we discussed in the introduction, processing trade plays a major role in the Chinese economy. Since the 1990s, processing trade in China has been increasingly related to the offshoring decisions of multinational enterprises (MNEs), and has become part of the growing trade driven by vertical specialization (Yi, 2003). According to Branstetter and Lardy (2006, pp. 38–39), China is able to export huge quantities of electronic and information technology products only because it imports most of the high value-added parts and components that go into these goods, and most such exports are assembled not by Chinese-owned firms but by foreign firms that are using China as an export platform.[15] Koopman et al. (2008) estimated that the share of foreign content in the exports of China's relatively sophisticated industries is about 80%, and FIEs tend to have higher foreign content in their exports than do indigenous Chinese firms. Feenstra and Hanson (2005, p. 758) observed that foreign factory ownership in China is more common in high-value-added industries than in low-value-added industries, which they explained with a model that features a tradeoff between ownership and control. Accordingly, we establish the following hypothesis:

Hypothesis 3. The export sophistication level of a Chinese industry depends positively on the share of processing exports of foreign-invested enterprises in the industry.

It is worth pointing out that government policies may play a key role in our hypothesized effects of FDI and processing trade. Rodrik (2006, p. 4) pointed out that “the extent to which China's sophisticated export basket has been a direct consequence of its unorthodox policy regime structure is not clear.” In our sample period of 2000–2005, the most significant policy event was China's WTO entry on December 11, 2001. China's WTO entry brought significant changes in policies towards FDI. Before 2002, the Chinese government implemented *The Catalogue for the Guidance of Foreign Investment Industries* (1997) which specifies various restrictions on foreign investors. In early 2002, the Chinese government replaced the old *Catalogue* with a new one. In the new catalogue, the number of items under “Encouraged Foreign Investment Industries” was increased from 186 to 262, and the number of items under “Restricted Foreign Investment Industries” was decreased from 112 to 75. One important change of China's FDI policy after WTO entry was the removal of restrictions on foreign ownership in various industries. For example, according to *The Catalogue for the Guidance of Foreign Investment Industries* (2002), for cross-border automobile transportation companies, foreign majority ownership would be permitted no later than December 11, 2002, and wholly foreign owned enterprises would be permitted no later than December 11, 2004. After China's WTO entry in 2001, Chinese central and local governments also enhanced their encouragement policies towards FDI in high-tech projects.[16] New policies were also issued that aim to increase technology-intensive processing exports and decrease resource-intensive processing exports. Since 2003, the Chinese government has been trying to encourage FIEs to shift their high-tech and high-value-added processing businesses and relevant research institutions to China to advance its industrial capabilities.[17] While we are not able to investigate directly the effects of government policies towards FDI and processing trade (due to data limitation), our examination of the compositional effects of FDI and processing trade helps to reveal the effects of government policies.[18]

The above discussion focuses on export sophistication across industries (PRODY), but the same theoretical hypotheses should apply also to within-product sophistication (PRICE). We hypothesize that a Chinese industry is expected to export product varieties of higher sophistication if it has a higher human capital base, a higher output share of OECD–WFOEs, and a higher share of processing exports by FIEs.

4. Data and specification

In this section we describe data and empirical specification. Our data comes from three sources. First, we use U.S. import data to compute product-level PRODY and PRICE, which has the advantage of being the most disaggregated product category at the 10 digit level of the Harmonized System (HS). Second, we construct industry-level explanatory variables from firm-level data drawn from China's Annual Survey of Industrial Firms (ASIF), a survey conducted by the National Bureau of Statistics of China covering all state-owned enterprises and other types of enterprises with annual sales of five million RMB or more. Third, we use data on processing

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[14] Dunning and Pearce (1977, p. 13) find that subsidiaries under less than 100% parent firm control accounted for a majority of all subsidiaries in low-technology British industries but only 11% in the high-technology industries. Mansfield and Romeo (1980) find that the technologies transferred by U.S. multinational enterprises to its JVs are of an older vintage than those transferred to WFOEs. Blodgett (1991) shows empirical evidence that multinational enterprises protect their technology assets from appropriation by local partners by taking a larger ownership share in the joint venture.

[15] Amiti and Freund (forthcoming) andVan Assche and Gangnes (2008) also argue along this line.

[16] For example, the Shanghai municipal government offered funds to overseas Chinese who set up software or integrated circuit design companies in Shanghai. If an overseas Chinese sets up such a company after January 1, 2002, with a minimum registered capital of RMB500,000, he or she may apply to the Shanghai municipal government for special funding up to RMB100,000. Source: *Wen Hui Bao*, June 1, 2002.

[17] Source: “China puts new curbs on processing trade,” *China Daily*, July 24, 2007.

[18] Wang and Wei's (forthcoming) city-level analysis is able to obtain estimated effects of tax-favored high-tech zones as direct evidence of government policies.

Table 1
Export sophistication of Chinese industries.

ISIC	Industry description	PRODY
Ten industries of highest export sophistication		
ISIC	*Industry description*	*PRODY*
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	22611
2222	Service activities related to printing	22124
2925	Manufacture of machinery for food, beverage and tobacco processing	22059
3511	Building and repairing of ships	22050
2924	Manufacture of machinery for mining, quarrying and construction	21836
3410	Manufacture of motor vehicles	21778
3313	Manufacture of industrial process control equipment	21658
1552	Manufacture of wines	21644
2914	Manufacture of ovens, furnaces and furnace burners	21575
2927	Manufacture of weapons and ammunition	20978
Ten industries of lowest export sophistication		
ISIC	*Industry description*	*PRODY*
1554	Manufacture of soft drinks production of mineral waters	8080
1543	Manufacture of cocoa, chocolate and sugar confectionery	7935
1542	Manufacture of sugar	7699
2010	Sawmilling and planning of wood	7160
1920	Manufacture of footwear	7134
1721	Manufacture of made-up textile articles, except apparel	6799
1810	Manufacture of wearing apparel, except fur apparel	6777
2022	Manufacture of builders' carpentry and joinery	6705
2029	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials	6651
1722	Manufacture of carpets and rugs	6020

Note: PRODY is averaged over the sample period of 2000–2005.

trade drawn from the China Customs General Administration's electronic trade database, which allows us to distinguish between processing trade by FIEs and indigenous Chinese firms. Because processing trade data is only available for the years 2000 to 2005, the sample period for our investigation is 2000 to 2005. All variables are constructed at the 4-digit ISIC level; there are 119 such industries in the sample. The appendix provides data details.

We use PRODY to measure the export structure sophistication level of Chinese industries, and PRICE to measure the relative price of goods exported by Chinese industries (and we interpret it as measure of within-product sophistication when appropriate). Among the 119 four-digit ISIC industries, the average annual growth rate of PRODY in the period of 2000–2005 ranges from −19.3% (ISIC = 1600, "Manufacture of tobacco products") to 16.4% (ISIC = 3530, "Manufacture of aircraft and spacecraft"), with mean 0.9% and standard deviation 5.2%. The average annual growth rate of PRICE ranges from −44.8% (ISIC = 2222, "Service activities related to printing") to 67.9% (ISIC = 3511, "Building and repairing of ships"), with mean −0.8% and standard deviation 10.4%. Table 1 reports the ten most sophisticated industries and ten least sophisticated industries in our dataset.

In the previous section we hypothesized that an industry's level of export sophistication depends positively on the human capital base of the industry (Hypothesis 1). One important determinant of variations in human capital across Chinese industries is the development level of the regions where exporting firms are located. China is a country with great diversity in regional development. As Table 2 shows, China's exports are mainly from costal provinces where the per capita GDP (PCGDP) levels are much higher than in inland provinces. To measure an industry's human capital base that reflects the development levels of the regions where exporting firms of the industry are located, we construct the following export-region-weighted PCGDP measure:

$$\mathrm{REGY}_n = \sum_{r \in R} s_{rn} Y_r \tag{7}$$

In this equation, R is the set of export regions, Y_r is PCGDP of region r, and s_{rn} is the export share of region r in total export value of industry n. Thus REGY is the average per capita GDP level of China's exporting provinces weighted by their export shares and constructed for each of the four-digit ISIC industries.

To investigate the effects of different types of exporting firms, we use their output shares of an industry as measures of their presence in the industry. FIE is the industry output share of FIEs, which measures the overall presence of FIEs in an industry. WFOE, JV, HMT, and OECD are all industry output shares of the respective types of FIEs, and SOE is the industry output share of state-owned enterprises (SOEs). To investigate the effects of processing exports, we use its share of total exports. PROCESS is the share of processing exports out of the total exports of an industry. PROCESS-F and PROCESS-D are the shares of processing exports by FIEs and by indigenous firms, respectively. We also consider technology and factor intensity variables. TEC is the share of intangible assets out of the industry's total assets.[19] CAP is industry fixed assets per worker (a proxy for capital intensity), and HUM is the industry average wage rate (a proxy for skilled labor intensity). Table 3 provides descriptions of the variables and their key summary statistics.

[19] Share of intangible assets is used as a proxy for technology intensity as R&D data are not available for some years. We also tried output share of new products, which makes little difference to our results.

Table 2
Economic indicators of China's provinces, 2005.

Province	Provincial PCGDP to China's PCGDP	Provincial export share	Provincial FDI share
Shanghai [a]	3.67	0.119	0.137
Beijing [a]	3.24	0.041	0.041
Tianjin [a]	2.55	0.036	0.039
Zhejiang	1.97	0.101	0.070
Jiangsu	1.75	0.161	0.182
Guangdong	1.74	0.313	0.197
Shandong	1.43	0.061	0.054
Liaoning	1.35	0.031	0.056
Fujian	1.33	0.046	0.051
Inner Mongolia	1.16	0.002	0.009
Hebei	1.05	0.014	0.015
Heilongjiang	1.03	0.008	0.008
Jilin	0.95	0.003	0.014
Xinjiang	0.93	0.007	0.001
Shanxi	0.89	0.005	0.005
Hubei	0.81	0.006	0.018
Henan	0.81	0.007	0.014
Chongqing [a]	0.78	0.003	0.005
Hainan	0.77	0.001	0.006
Hunan	0.74	0.005	0.011
Ningxia	0.73	0.001	0.003
Qinghai	0.72	0.000	0.000
Shaanxi	0.71	0.004	0.009
Jiangxi	0.67	0.003	0.013
Tibet	0.65	0.000	0.000
Sichuan	0.65	0.006	0.011
Guangxi	0.63	0.004	0.010
Anhui	0.62	0.007	0.011
Yunnan	0.56	0.003	0.006
Gansu	0.53	0.001	0.002
Guizhou	0.36	0.001	0.002

Source: *China Statistical Yearbook*, 2006. PCGDP denotes per capita GDP.
[a] Municipality directly under the central government (equivalent to province).

We use two regression specifications in our empirical investigation. First, we use a level regression equation specified as follows:

$$log\,\mathbf{S}_{nt} = \alpha_n + \alpha_t + \alpha_{1t} log\,\text{REGY}_{nt} + \alpha_{2t} log\,\mathbf{FOR}_{nt} + \alpha_{3t} log\,\mathbf{PROCESS}_{nt} + \alpha_{4t} log\,\mathbf{OTHER}_{nt} + \varepsilon_{nt}. \tag{R1}$$

In Eq. (R1), **S** denotes the dependent variable (PRODY or PRICE), α_n denotes industry fixed effects, α_t denotes year fixed effects, **FOR** denotes the set of variables that measure the presence of different types of FIEs, **PROCESS** denotes the set of variables that measure the presence of different types of processing exports, **OTHER** denotes the set of intensity variables (TEC, CAP, and HUM), and ε is an error term.

Second, we use a difference regression equation specified as follows:

$$\Delta log\,\mathbf{S}_{nt} = \beta_n + \beta_t + \beta_{1t} \Delta log\,\text{REGY}_{nt} + \beta_{2t} \Delta log\,\mathbf{FOR}_{nt} + \beta_{3t} \Delta log\,\mathbf{PROCESS}_{nt} + \beta_{4t} \Delta log\,\mathbf{OTHER}_{nt} + v_{nt}. \tag{R2}$$

In Eq. (R2), β's are parameters and ν is an error term. The difference regression equation estimates the link between changes in export sophistication and changes in the hypothesized determinants. This is useful as the evolution of Chinese export characteristics is pronounced in the time dimension. Note that the time-differencing level Eq. (R1) would yield a difference equation *without* industry fixed effects, while the difference Eq. (R2) includes industry dummies (β_n) to control for the effects of unobserved industry features on *changes* in export sophistication. In this sense, Eq. (R2) is more general than Eq. (R1) in estimating the effects of the explanatory variables.

5. Empirical results

5.1. PRODY level regressions

Table 4 reports results from the PRODY level regressions. Notice first that the estimated coefficient on REGY is positive and statistically significant in regressions (4.1)–(4.5); it is however statistically insignificant in regression (4.6) which includes all of the hypothesized determinants of PRODY. Thus there is no conclusive evidence supporting Hypothesis 1.

Table 3
Variable description and summary statistics, 2000–2005.

Variable	Description	Mean	SD	Growth
PRODY	Index of export structure sophistication	14314	4531	0.008
PRICE	Unit value of exports of China relative to that of the world	0.637	0.354	−0.009
REGY	Weighted average of per capita GDP of exporting regions	10321	1687	0.067
FIE	Output share of all foreign-funded firms	0.488	0.231	−0.024
WFOE	Output share of wholly foreign owned firms	0.240	0.191	0.136
JV	Output share of foreign joint ventures	0.248	0.145	−0.082
OECD	Output share of foreign funded firms not from Hong Kong, Macao and Taiwan	0.294	0.170	0.002
HMT	Output share of foreign funded firms from Hong Kong, Macao and Taiwan	0.201	0.150	−0.034
OECD-WFOE	Output share of wholly foreign owned non-HMT firms	0.134	0.127	0.173
HMT-WFOE	Output share of wholly foreign owned HMT firms	0.104	0.111	0.095
OECD-JV	Output share of non-HMT foreign joint ventures	0.160	0.116	−0.080
HMT-JV	Output share of HMT foreign joint ventures	0.097	0.087	−0.112
SOE	Output share of state-owned firms	0.127	0.186	−0.213
PROCESS	Share of processing exports in total exports	0.414	0.261	−0.039
PROCESS-F	Share of processing exports by foreign funded firms in total exports	0.291	0.215	−0.011
PROCESS-D	Share of processing exports by indigenous Chinese firms in total exports	0.123	0.140	−0.127
TEC	Share of intangible assets in total assets	0.027	0.184	0.022
CAP	Ratio of fixed assets to number of workers	101.7	90.1	0.023
HUM	Industry average real wage rate	14.9	7.7	0.113

Notes: All variables are at the 4-digit ISIC industry level. Number of observations is 681. Growth is computed as mean of annual growth rates of five years, 2001 to 2005.

In regression (4.1), we find that an industry's PRODY is not related to FIE, which measures the overall presence of FIEs in the industry. In regression (4.2), we break the FIEs into WFOEs and JVs, and the results show a positive estimated coefficient on WFOEs that is statistically significant at the 1% level. In regression (4.3), we further break the FIEs into four groups, and the results show a positive and statistically significant estimated coefficient on OECD-WFOE, which measures the presence of WFOEs funded by non-HMT (mainly OECD) countries. The estimated coefficient on OECD-WFOE remains positive and statistically significant in regression (4.6) which includes all of the hypothesized determinants. Thus the results of Table 4 show strong evidence supporting Hypothesis 2. These results highlight the importance of distinguishing between the different types of FIEs in studying China's export sophistication.[20]

In regression (4.4), we examine the partial correlation between PRODY and PROCESS, which is the share of processing exports out of the total exports of an industry, and find that the estimated coefficient on PROCESS is statistically indifferent from zero. In regression (4.5) we distinguish between the processing exports of FIEs and of indigenous Chinese firms, and the finding shows a positive and statistically significant estimated coefficient on PROCESS-F, and a negative and statistically significant estimated coefficient on PROCESS-D. This finding remains in regression (4.6) which includes all of the hypothesized determinants of PRODY. We view this finding as evidence supporting Hypothesis 3. The results from regression (4.6) show that the contributions of FIEs to China's export sophistication are due to the technologically advanced firms (OECD-WFOEs), and are related to the processing exports of FIEs. On the other hand, the negative estimated coefficient on PROCESS-D implies that processing exports by indigenous Chinese firms are of low levels of sophistication.[21]

Regression (4.6) includes industry intensity variables of technology assets (TEC), physical capital (CAP) and human capital (HUM). The estimated coefficients on all these variables are statistically insignificant, and our experiments indicate that their effects are absorbed by industry dummies.[22] The estimated coefficient on SOE, which measures presence of SOEs in an industry, is found to be statistically insignificant.

5.2. PRICE level regressions

As discussed in previous sections, it is useful to examine China's export sophistication both across products and within a product category to see if it reveals any patterns. In this study, we use the relative unit value of goods exported by a Chinese industry (PRICE) to measure within-product sophistication of the industry. We note that PRICE may be a result of product sophistication, but may also be a result of other factors such as industry market structure, cost conditions, and exchange rate exposure.

[20] It is interesting to note that while Wang and Wei (forthcoming) did not find any positive direct effects of FIEs on export structure sophistication of Chinese cities, they did find a major difference between the estimated effects of WFOEs and JVs: the former is not directly associated with export structure sophistication, while the latter is negatively associated with export structure sophistication.

[21] Wang and Wei (forthcoming) find that export structure sophistication of Chinese cities is positively associated with processing exports in policy zones, but negatively associated with processing exports outside policy zones. They point out that processing trade inside policy zones is dominated by FIEs, while processing trade outside policy zones is relatively labor-intensive.

[22] Without industry dummies, the estimated coefficients of these intensity variables are statistically significant, and their signs are consistent with predictions of the conventional trade theory.

Table 4
PRODY level regressions, 4-digit ISIC industries, 2000–2005.

	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)
log REGY	0.348	0.278	0.316	0.306	0.279	0.193
	(2.25)**	(1.65)*	(1.87)*	(2.00)**	(1.83)*	(1.08)
log FIE	0.007					
	(0.55)					
log WFOE		0.025				
		(3.03)***				
log JV		−0.005				
		(0.53)				
log OECD-WFOE			0.022			0.021
			(3.12)***			(2.83)***
log HMT-WFOE			0.003			−0.002
			(0.51)			(0.30)
log OECD-JV			−0.006			−0.013
			(0.66)			(1.44)
log HMT-JV			−0.002			−0.006
			(0.27)			(0.94)
log SOE	0.009	0.009	0.007			0.005
	(1.48)	(1.52)	(1.28)			(0.84)
log PROCESS				0.010		
				(0.54)		
log PROCESS-F					0.027	0.024
					(2.18)**	(1.90)*
log PROCESS-D					−0.019	−0.023
					(2.10)**	(2.57)**
log TEC						−0.028
						(1.29)
log CAP						0.068
						(1.49)
log HUM						−0.080
						(1.35)
Constant	6.413	7.090	6.757	6.770	7.007	7.597
	(4.61)***	(4.68)***	(4.48)***	(4.91)***	(5.10)***	(4.89)***
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	681	681	681	669	669	669
R-squared	0.82	0.82	0.82	0.82	0.82	0.83

Notes: The dependent variable is log PRODY of 4-digit ISIC industries. Absolute values of *t* statistics are in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

Table 5 reports results from PRICE level regressions. In regressions (5.1)–(5.3), we examine partial correlations between PRICE and the presence of FIEs and SOEs. The results show that estimated coefficients are positive on all types of FIEs, with almost all of them at the 1% level of statistical significance. SOE also shows a positive and statistically significant estimated coefficient.

In regressions (5.4) and (5.5), we examine the role of processing trade. Regression (5.4) shows a negative estimated coefficient on PROCESS, which says that the relative export prices of a Chinese industry are lower the higher the share of processing exports in the industry's total exports. This result suggests that China's processing exports contain mainly product varieties of low sophistication compared to the product varieties exported by other countries to the U.S. market. Regression (5.5) separates processing exports of FIEs and those of indigenous Chinese firms; the results show a positive estimated coefficient on PROCESS-F and a negative estimated coefficient on PROCESS-D, both of which are statistically significant at the 1% level.

In regression (5.6), we estimate the effects of all variables simultaneously. The estimated coefficient on REGY is positive and statistically significant, which supports the role of human capital stated in Hypothesis 1. We find that the estimated coefficient on OECD-WFOE remains positive and statistically significant at the 1% level, and its point estimate does not change much from regression (5.3); this finding supports Hypothesis 2. Notice that point estimates on other types of FIEs all see a reduction as compared to regression (5.3) and their statistical significance also falls. While the estimated coefficient on PROCESS-F remains positive and statistically significant at the 1% level, its point estimate falls from 0.086 in regression (5.5) in which presence of FIEs is not controlled for, to 0.068 in regression (5.6) in which presence of FIEs is controlled for. These results suggest that all types of FIEs in China export product varieties of relatively high sophistication, whether they are engaging in processing exports or normal exports; FIEs, however, have a positive association with a higher PRICE that is *distinctively* related to the processing exports they do; this finding supports Hypothesis 3. Regression (5.6) also shows that the estimated coefficient on PROCESS-D remains negative and statistically significant at the 1% level as in regression (5.5). The estimated coefficient on SOE is found to be statistically insignificant.

It is useful to note the consistency between the results estimated from the PRODY regression (4.6) and those estimated from the PRICE regression (5.6). Both PRODY and PRICE are positively associated with presence of OECD-WFOE firms and processing exports

Table 5
PRICE level regressions, 4-digit ISIC industries, 2000–2005.

	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)
log REGY	0.172	0.593	0.704	0.168	0.061	0.469
	(0.72)	(2.27)**	(2.71)***	(0.71)	(0.27)	(1.76)*
log FIE	0.062					
	(3.30)***					
log WFOE		0.040				
		(3.18)***				
log JV		0.059				
		(3.85)***				
log OECD-WFOE			0.032			0.031
			(2.94)***			(2.80)***
log HMT-WFOE			0.025			0.012
			(2.61)***			(1.24)
log OECD-JV			0.036			0.022
			(2.68)***			(1.64)*
log HMT-JV			0.023			0.017
			(2.53)**			(1.89)*
log SOE	0.020	0.016	0.018			0.012
	(2.29)**	(1.84)*	(1.98)**			(1.42)
log PROCESS				−0.073		
				(2.59)***		
log PROCESS-F					0.086	0.068
					(4.69)***	(3.61)***
log PROCESS-D					−0.077	−0.077
					(5.76)***	(5.74)***
log TEC						0.025
						(0.77)
log CAP						0.083
						(1.22)
log HUM						−0.138
						(1.55)
Constant	−0.723	−4.388	−5.245	−0.881	0.119	−3.248
	(0.34)	(1.88)*	(2.26)**	(0.41)	(0.06)	(1.40)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	681	681	681	669	669	669
R-squared	0.60	0.61	0.62	0.60	0.63	0.65

Notes: The dependent variable is PRICE of 4-digit ISIC industries. Absolute values of *t* statistics are in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

by FIEs, and negatively associated with processing exports by indigenous Chinese firms. Both PRODY and PRICE of an industry see a positive association (although statistically insignificant in 4.6) with the human capital level of the Chinese regions intensively exporting in the industry. The consistency between the two sets of results suggests that there may exist some common factors that determine both the across-product and within-product export sophistication of Chinese industries.

The results of our study and those of Wang and Wei (forthcoming) provide evidence for cross-checking. Wang and Wei (forthcoming) found that unit values of exports by a Chinese city are higher the higher the presence of FIEs in the city, which we also find with regard to PRICE of a Chinese industry. Wang and Wei (forthcoming) found that processing exports, both inside and outside policy zones, have higher export unit values; we find however that PRICE is negatively related to total processing exports, and it is positively related only to processing exports by FIEs. Wang and Wei (forthcoming) found a negative partial correlation between unit values and the export share of SOEs, while our results show that PRICE is either not related or positively related to SOEs. The different results of the two studies may be caused by differences in the unit of analysis (industry versus city).

5.3. PRODY difference regressions

As discussed in the previous section, given the pronounced variations in China's export sophistication across time, we also estimate a time-difference regression equation. Table 6 reports results from the PRODY difference regressions. Notice first that the estimated coefficient on REGY is positive but statistically insignificant; the effects of regional development (REGY growth) are likely to have been absorbed in the effects of the year dummies which we control for. In regression (6.1), we find that neither FIE nor SOE are statistically significant, which is consistent with the results from level regression (4.1). In regression (6.2), we find that WFOE shows a positive estimated effect, while JV shows a negative estimated effect, both of which are statistically significant at the 5% level. When FIEs are classified in four types as in regression (6.3), we find that both OECD-WFOE and HMT-WFOE show positive estimated coefficients, while both OECD-JV and HMT-JV show negative estimated coefficients (the latter is not statistically

Table 6
PRODY difference regressions, 4-digit ISIC industries, 2001–2005.

	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)	(6.6)
Δlog REGY	0.186	0.031	0.135	0.142	0.121	0.141
	(0.96)	(0.15)	(0.67)	(0.73)	(0.63)	(0.66)
Δlog FIE	−0.018					
	(1.36)					
Δlog WFOE		0.021				
		(2.07)**				
Δlog JV		−0.028				
		(2.44)**				
Δlog OECD-WFOE			0.022			0.024
			(2.96)***			(2.97)***
Δlog HMT-WFOE			0.014			0.013
			(2.02)**			(1.85)*
Δlog OECD-JV			−0.018			−0.016
			(1.75)*			(1.49)
Δlog HMT-JV			−0.008			−0.007
			(1.24)			(0.99)
Δlog SOE	0.005	0.009	0.007			0.005
	(0.85)	(1.45)	(1.17)			(0.78)
Δlog PROCESS				0.005		
				(0.19)		
Δlog PROCESS-F					0.033	0.026
					(2.10)**	(1.64)*
Δlog PROCESS-D					−0.018	−0.020
					(1.81)*	(1.94)*
Δlog TEC						−0.023
						(1.04)
Δlog CAP						−0.012
						(0.21)
Δlog HUM						−0.003
						(0.04)
Constant	−0.051	−0.046	−0.057	−0.050	−0.053	−0.060
	(2.09)**	(1.84)*	(2.25)**	(1.98)**	(2.11)**	(2.30)**
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	566	566	566	546	546	546
R-squared	0.10	0.13	0.14	0.10	0.12	0.16

Notes: The dependent variable is Δlog PRODY, where Δ denotes yearly difference. Values of t statistics are in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

significant). These results indicate that export structure sophistication of a Chinese industry tends to increase more rapidly the faster the shift of FDI composition of the industry towards WFOEs and away from JVs.

In regression (6.4), PROCESS does not show a statistically significant effect. In regression (6.5), PROCESS-F shows a positive estimated effect, and PROCESS-D shows a negative estimated effect. These results are consistent with the ones obtained from level regressions (4.4) and (4.5). When we include both variables of firm types and processing exports in regression (6.6), we find that OECD-WFOE and PROCESS-F have positive estimated coefficients and PROCESS-D has a negative estimated coefficient, the same as in level regression (4.6); notice that the point estimates of the coefficients of these variables are quite similar in the level and difference regressions. In regression (6.6), HMT-WFOE also shows a positive estimated coefficient, which differs from the result of level regression (4.6). This suggests that while industries with higher HMT-WFOE presence do not have higher export sophistication levels, industries with faster growth of HMT-WFOE presence tend to see more rapid export sophistication growth.

By performing some simple calculations we can get estimates of the quantitative importance of the roles played by FIEs and processing exports. During the sample period of 2000–2005, output share of OECD-WFOEs in Chinese industries grew on average by 17.3% annually, and output share of HMT-WFOEs grew on average by 9.5% annually (Table 3). Using point estimates from regression (6.6), we can calculate the total effect of WFOE growth on PRODY growth as equal to $0.024\times0.173+0.013\times0.095=0.005$. During the sample period, the share of processing exports by FIEs fell on average by 1.1%, while the share of processing exports by indigenous Chinese firms fell on average by 12.7% (Table 3). Using point estimates from regression (6.6), we can calculate the total effect of processing export growth on PRODY growth as equal to $0.026\times(-0.011)+(-0.02)\times(-0.127)=0.002$. Since PRODY grew by 0.8% annually during the period, the growing presence of WFOEs in Chinese industries contributed about $0.005/0.008=63\%$ to PRODY growth, and the falling share of processing exports (by both FIEs and indigenous firms) in Chinese industries contributed about $0.002/0.008=25\%$ to PRODY growth. Taken together, the rising shares of FDI in the form of WFOEs and falling shares of processing exports in total exports contributed 88% to rising export structure sophistication of Chinese industries in the period 2000–2005.

Table 7
PRICE difference regressions, 4-digit ISIC industries, 2001–2005.

	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)	(7.6)
Δlog REGY	0.071	−0.052	−0.116	−0.043	−0.077	0.169
	(0.28)	(0.19)	(0.42)	(0.16)	(0.30)	(0.59)
Δlog FIE	−0.025					
	(1.42)					
Δlog WFOE		−0.000				
		(0.02)				
Δlog JV		−0.022				
		(1.40)				
Δlog OECD-WFOE			−0.004			0.011
			(0.44)			(1.01)
Δlog HMT-WFOE			0.012			0.012
			(1.28)			(1.29)
Δlog OECD-JV			−0.028			−0.020
			(2.00)**			(1.41)
Δlog HMT-JV			−0.010			−0.013
			(1.11)			(1.33)
Δlog SOE	0.027	0.030	0.031			0.028
	(3.33)***	(3.64)***	(3.72)***			(3.30)***
Δlog PROCESS				0.006		
				(0.18)		
Δlog PROCESS-F					0.052	0.037
					(2.44)**	(1.79)*
Δlog PROCESS-D					−0.039	−0.028
					(2.84)***	(2.05)**
Δlog TEC						0.024
						(0.80)
Δlog CAP						−0.217
						(2.70)***
Δlog HUM						−0.112
						(1.21)
Constant	−0.063	−0.055	−0.050	−0.062	−0.069	−0.067
	(1.91)*	(1.63)	(1.48)	(1.83)*	(2.04)**	(1.93)*
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	566	566	566	546	546	546
R-squared	0.23	0.23	0.24	0.21	0.24	0.29

Notes: The dependent variable is ΔPRICE, where Δ denotes yearly difference. Values of *t* statistics are in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

5.4. PRICE difference regressions

Table 7 reports results from the PRICE difference regressions. Note that the dependent variable is ΔPRICE rather than Δlog PRICE. The former performs much better empirically than the latter, so we choose it as the dependent variable given that we do not know the true functional form of the underlying relationship.

In all regressions that include the SOE variable, we find that it is positive and statistically significant at the 1% level. As we learn from Table 3, SOE shares of industry output *declined* sharply in the sample period at an average annual rate of 21.3%. Thus, the positive estimated coefficient on SOE implies that an industry would see a larger drop in the relative export price (PRICE) the faster the decline of SOE presence in the industry. Given that PRICE fell on average by 0.017 (in level) annually in the sample period, the contribution of falling presence of SOEs to falling PRICE equals $0.028 \times (-0.213) / (-0.017) = 35\%$. Regression (7.6) shows that a change in PRICE is not related to changes in the presence of all types of FIEs. Since the benchmark firm group of this regression is non-state Chinese firms, the results of regression (7.6) imply that the trend of falling relative prices of Chinese exports is largely associated with the privatization of Chinese state-owned firms to non-state firms; changes of FDI composition do not have a significant impact on change in PRICE.

We find from regression (7.6) that change in PRICE is positively related to change in processing exports by FIEs and negatively related to change in processing exports by indigenous Chinese firms. As Table 3 indicates, shares of processing exports by both FIEs and indigenous Chinese firms fell in the sample period, with the processing export share of FIEs falling at an average annual rate of 1.1%, and the processing export share of domestic firms falling at an average annual rate of 12.7%. Using mean values of the variables (Table 3) and point estimates of their coefficients, we estimate that the contribution of the falling share of processing exports of FIEs to falling PRICE equals $0.037 \times (-0.011) / (-0.017) = 2.4\%$, while the falling share of processing exports of indigenous Chinese firms has an effect of *increasing* PRICE, whose effect is estimated to equal $0.028 \times 0.127 / (-0.017) = -21\%$. Taking these two effects together, we conclude that the decline of the processing export share in China played a role in offsetting the trend of falling PRICE of Chinese exported goods. As the importance of processing exports by indigenous Chinese firms falls, Chinese exports tend to see an increase in their prices relative to those exported by other countries, which may correspond to an increase in product sophistication of Chinese export varieties.[23]

6. Conclusion

China's export structure has shown a rapid shift towards more sophisticated industries. Some studies find that China's overall export sophistication level is exceptionally high (Rodrik, 2006; Schott, 2008). What explains the high sophistication level and the rapid upgrade of China's export structure? This question has drawn much attention but has not been adequately studied.

This paper examines variations in level of export sophistication across China's manufacturing industries, focusing on the role of FDI and processing trade. Several authors argued that China's high export sophistication is mainly a result of FIEs exporting from China as well as processing trade in which sophisticated intermediate goods are imported to assemble final goods for exporting (Branstetter & Lardy, 2006; Gilboy, 2004). There is evidence supporting such arguments (Amiti & Freund, forthcoming; Van Assche & Gangnes, 2008), but also evidence against them. In an analysis of variations in level of export sophistication across Chinese cities, Wang and Wei (forthcoming) found that neither processing trade nor FDI seems to have played an important role in generating the increased overlap between China's export structure and that of advanced countries; they identified human capital and government policy of high-tech zones as key explanatory variables of the differences of export structure sophistication among Chinese cities.

Our study provides new evidence to the literature. Consistent with the findings of Wang and Wei (forthcoming), the *overall* presence of FIEs and processing exports shows statistically insignificant effects in our industry analysis. We find, however, that a Chinese industry's export sophistication level is positively related to the presence of OECD-WFOEs in the industry, but is not related to the presence of other types of FIEs including HMT-WFOEs. We also find that a Chinese industry's export sophistication is positively related to the share of processing exports of FIEs, but is negatively related to the share of processing exports of indigenous Chinese firms. The distinction between OECD and HMT firms, which was not drawn by Wang and Wei (forthcoming), allows us to identify a positive effect from OECD-WFOEs but no effect from HMT-WFOEs. Our data also distinguishes between processing exports of FIEs and of indigenous Chinese firms, which allows us to identify a positive correlation between the export sophistication level and processing exports of FIEs, and a negative correlation between the export sophistication level and processing exports of indigenous Chinese firms. We also perform an analysis on the relative export prices of Chinese goods, which is used as proxy for within-product export sophistication; the results from this analysis are consistent with those from the analysis of across-product export sophistication.

Our results provide a useful first step to exploring the deeper reasons of China's rising export sophistication. In our sample period of 2000–2005, there was a pronounced compositional shift of FDI in China towards the form of WFOEs; we estimate that this shift contributed 63% to China's rising export structure sophistication in the period. The sample period also witnessed a declining trend of the share of processing exports in total exports, especially of the processing exports of indigenous Chinese firms; we estimate that this trend contributed 25% to China's rising export structure sophistication in the period. The two trends were facilitated by changes in Chinese government policies towards FDI and processing trade, in particular policy changes related to China's WTO entry in 2001.[24] It would be useful for future research to investigate the effects of such policies on the sophistication of Chinese exports.

Identifying the sources of China's export sophistication has important welfare implications. If China's rising export sophistication is driven by WFOEs, we must ask how much China benefits from this rising export sophistication. If China's export structure upgrading is driven by processing trade in which firms import sophisticated intermediate inputs to assemble sophisticated final goods, we must ask if there is any skill upgrading in China's value added. This paper is not able to address such questions as it requires more detailed data, but there is no doubt that exploring answers to these important questions should be at the top of future research agendas.

Appendix A

We use U.S. merchandise import data from Feenstra, Romalis and Schott (2002) for 1992–2001 and the USA Trade Online Database for 2002–2005. The data is disaggregated by Harmonized System (HS) to the 10 digit level and recorded by U.S. Customs. For each HS10 product, there is information on exporting country, value, and quantity. We use value and quantity of "general imports", which are imports as they come off the dock. The HS10 data are 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); 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 every country-product observation. Using 2001 as an example, there are 247,104 country-product observations in the raw data, from which we obtain 226,583 unique country-product observations that show positive

[23] In regression (7.6), we find a negative estimated coefficient on Δlog CAP that is statistically significant at the 1% level. If we drop Δlog CAP in the regression, the estimated coefficient on Δlog HUM becomes negative and statistically significant. Thus, there seems to be a robust negative association between change in an industry's PRICE and changes in capital/skill intensities of the industry. In other words, larger drops in PRICE occurred in industries with higher growth of capital/skill intensities. One possible interpretation is that industries with higher growth of capital/skill intensities are the ones with more competition, and hence prices tend to decrease by a larger amount in such industries.

[24] Fung, Iizaka, and Tong (2004) discussed China's FDI policy adjustments that led to an increasing share of WFOEs. HKTDC (2007) discussed China's processing trade policy changes that led to an expansion of the list of products under the prohibited and restricted categories to reduce processing trade of products with low value-added, high pollution, and high energy consumption and resource consumption.

import values. Among these observations, there are 36,112 observations for which the quantity units could not be measured (the dataset shows a positive import value but zero import quantity), which gives rise to a sample of 190,471 observations. We use concordances from the UNCTAD to assign products to 4-digit ISIC (revision 3) industries, and use manufacturing industries (classified as 15–37 by 2-digit ISIC codes) in our study.

To compute the index of export structure sophistication (PRODY), we use PCGDP (GDP per capita, PPP, constant 2000 international $) from World Development Indicator (WDI) of the World Bank. The compatible data for Taiwan is from IMF World Economic Outlook Database. There are 173 countries with PCGDP in some years. We drop countries with missing PCGDP in any year, which leaves us 157 countries. There are some cases where U.S. import data contains country code values that are actually data for a country group; among the 157 countries, there are seven such country groups. We use GDP and population data from WDI to compute PCGDP for such country groups. In the end we have 141 countries (including seven country groups) that have PCGDP for every year from 1992 to 2005. We choose 1992 as the starting year mainly because it allows a maximum number of countries in our sample. All the 141 countries exported to the U.S., with only Iran and Vietnam having no recorded exports in some years. This gives us a consistent sample of countries so as to avoid the omitted country bias discussed in Hausmann et al. (2007).

Data on firms are drawn from China's Annual Survey of Industrial Firms (ASIF). Conducted by the National Bureau of Statistics of China, the annual survey covers all state-owned enterprises and other types of enterprises with annual sales of five million RMB or more, and provides detailed information on firms' identification, operations and performance. In the ASIF data, industries are classified by the 1994 version of Chinese Standard Industry Classification (GB/T 4754-1994) in years before 2003 and by the 2002 version (GB/T 4754-2002) in years after 2003. We first convert 1994 codes to 2002 codes, and then to ISIC codes (revision 3). We define foreign-invested firms (FIEs) as firms with 10% or more equity shares held by MNEs from other countries and regions, including Hong Kong, Macao and Taiwan.

Data on processing trade are drawn from China Customs General Administration's electronic trade database, which exclusively records China's international trade transactions of goods. Processing trade includes two main types of transactions: processing and assembling, and processing with imported materials. Processing trade by FIEs is that conducted by three types of FIEs: wholly owned FIEs, foreign invested joint ventures, and Sino-foreign cooperative firms. Indigenous Chinese firms refer to all non-FIE firms. We construct variables of processing exports at the 4-digit ISIC level. Processing trade data are available for years from 2000 to 2005.

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