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# Export sophistication and economic growth: Evidence from China☆

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ABSTRACT

We consider the effect of export sophistication on economic performance by appealing to regional variation within one single country (China) over the 1997–2009 period. We find evidence in support of Hausmann, Hwang and Rodrik (2007), in that regions specializing in more sophisticated goods subsequently grow faster. We find substantial variation in export sophistication at the province and prefecture level, controlling for the level of development, and that this sophistication in turn drives growth. Our results suggest that these gains are limited to the ordinary export activities undertaken by domestic firms: no direct gains result from either processing trade activities or foreign firms, even though these are the main contributors to the global upgrading of China's exports. As such, the extent of assembly trade and foreign entities should be distinguished in order to measure the true movement in a country's technology and the contribution of exports to economic growth.



## 1. Introduction

Since the early 1990s, China has integrated into world trade at an astounding pace. Chinese exports more than quintupled between 1992 and 2007, growing faster than the national economy. The functioning of China's economy has been radically transformed, moving from an isolated position with exports of less than 10% of GDP in 1980 to a highly-integrated economy, with an export ratio of more than 37% in 2007. This process has been accompanied by a no less impressive diversification of China's trade, as its manufactured exports pervaded all sectors of world trade, from low-technology textiles to high-tech electronics and computers.

A number of aspects of this trade integration have however puzzled economists. One is the rapid *upgrading* of China's exports: economists (and world consumers) have noticed the impressively broad range of China's export products since the mid-nineties, and in particular, the ability of Chinese producers to export capital- and skill-intensive products, high-technology products, and in general products that are usually considered as belonging to the area of specialization of more developed countries. Rodrik (2006) notes that China is an outlier regarding the overall *sophistication* of its exports: according to the sophistication index of Hausmann et al. (2007), which estimates the average "income level of a country's exports", China's export bundle is similar to that of a country with a level of income per-capita three times larger than China. Using an alternative indicator, Schott (2008) also finds that China's export bundle is increasingly overlapping with that of the world's most-developed economies, and that this overlap cannot be entirely explained by factor endowments.[1]

This phenomenon has given rise to two related debates in the literature. The first asks whether this discrepancy between China's export structure and its level of development (sometimes called the "China-is-special" result) is an artifact due to the improper measurement of export sophistication.[2] The second considers the potential contribution of export upgrading to China's real growth. We here rely on detailed trade data at the sub-national level in China over the 1997–2009 period to investigate these two related issues empirically.

A number of researchers have questioned the claim made in Rodrik (2006) and Schott (2008) that there is something special about Chinese exports. The importance of processing trade[3] in China's

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[1] See also Fontagné et al. (2008).

[2] We are grateful to an anonymous referee for pointing out the relevance of this literature.

[3] The terms 'processing', or 'assembly', trade are used interchangeably to refer to the operations of firms which import inputs in order to assemble them in China and re-export the finished products.

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export sector is one possible reason for the overvaluation of Chinese exports' sophistication, as many of the high-technology goods exported by China are produced using labor-intensive processes and imported inputs. The sophistication of these exports thus includes the technology embedded in the imported inputs, and not necessarily any greater degree of complexity or technology in the Chinese final assembly process. Moreover, a considerable share of high-technology exports comes from partially or wholly foreign-owned firms (mainly operating in the assembly-trade sector): this raises the question of whether the observed upgrading of Chinese exports reflects the genuine adoption of technology at the local level (Amiti and Freund, 2010; Lardy, 2005; Lemoine and Ünal-Kesenci, 2004; Wang and Wei, 2010). These concerns are backed up by statistics on Chinese trade. In 2007, 54% of Chinese exports were in the processing trade sector; the analogous figure is 85% for high-technology exports. Processing trade activities are also dominated by foreign entities: in 2007, 82% of processing-trade exports, and 91% of high-tech processing-trade exports, came from foreign firms. Koopmans et al. (2008) develop a general formula for computing the domestic and foreign components of pervasive processing-trade exports, and calculate that the foreign share of value-added in China's exports is around 50%, which is far higher than in most other countries.[4] They also find that this foreign content is higher in more sophisticated sectors, such as electronic devices and telecommunication equipment (about 80%). Yao (2009) argues that once China's processing-trade regime is taken into account, Chinese exports no longer look very different from those in other countries with similar levels of development, a point also made by Van Assche and Gangnes (2010). It is in addition underlined that the uneven distribution of income, and of exports, across China's provinces should be taken into consideration when establishing any "China-is-special" phenomenon. In China, the provinces that export the most, and the most sophisticated products, are also the richest: there thus may not be much of a gap between income levels and export sophistication if we look at province-level data (see e.g. Xu, 2010).

The second related debate refers to the contribution of export upgrading to China's growth. Theoretically, this is linked to the question of whether reshaping the structure of production beyond the boundaries established by factor endowments (physical and human capital, and natural resources) yields any growth benefits. Standard trade theory with its focus on comparative advantage would answer in the negative. However, a considerable theoretical literature based on endogenous growth has proposed models which go beyond this standard framework to show that production structure is a crucial determinant of economic performance.[5] These models consider the process of learning and the adoption of new technologies as being costly. In this framework, beyond specializing in the sectors with comparative advantage, there are additional gains to specializing in products with greater positive externalities. Policies which favor this discovery process, such as encouraging technological learning and technology imports, may lead to higher growth rates. Empirical support for this hypothesis has recently been provided by Hausmann et al. (2007), who use cross-country panel regressions to show that countries acquiring the capability to export more sophisticated goods grow faster, controlling for initial income levels and factor endowments. They hence argue that "what a country exports matters".

The measurement of China's export upgrading and its impact on growth are closely related. If indeed, as argued by many, this upgrading can be entirely attributed to the assembly sector, then we may expect the "China-is-special" result to break down, once we distinguish processing from non-processing exports. If, in addition, the sophistication of Chinese exports reflects regional differences in income, then export sophistication may have no additional predictive power with respect to the real growth rates of provinces, once initial levels of income have been controlled for.

We here use sub-national trade data differentiating between processing trade and ordinary (i.e. non-processing) trade, as well as between exports by domestic and foreign-owned firms, and contribute to the literature in three different ways.

We first estimate the upgrading of China's exports by measuring export sophistication separately for ordinary and processing-trade transactions and for domestic and foreign firms.[6] This decomposition shows that almost three quarters of China's export sophistication growth can be attributed to processing trade, in line with previous findings (Amiti and Freund, 2010; Lemoine and Ünal-Kesenci, 2004; Wang and Wei, 2010). In addition, virtually all of processing-trade's contribution to China's export sophistication came from foreign firms. We however find that the recent upgrading of China's trade has also involved domestic producers, and especially their ordinary trade activities which account for the remaining quarter of this growth. The per capita income level associated with exports by domestic entities increased by 15.5% between 1997 and 2007 to reach a figure of 12,500$, similar to that in Lithuania, a country which is three times richer than China in PPP per capita terms. This figure remains however lower than that of foreign entities, which rose by 25.7% over the period to reach 15,776$, a figure similar to that in the UK, a country seven times richer than China in PPP per capita terms. Second, we estimate the relationship between export sophistication and real growth in China. As we rely on regional variations within a single country (China), we provide a test of Hausmann et al. (2007) model relating production structure to economic growth, with the advantage that, by comparing China's provinces, we can mitigate the problems of omitted variables related to different legal and institutional systems that arise in cross-country analysis. The cross-country empirical patterns found in Hausmann et al. (2007) continue to hold across the regions within China. We thus confirm the validity of Hausmann et al. (2007) in the Chinese context: regions specializing in sophisticated goods grow faster. Our results contrast with the criticisms of Yao (2009) and Xu (2010) by showing that, even at the sub-national level, export sophistication varies substantially, controlling for income, and that this difference in turn matters for growth. The relation of export sophistication to growth is robust to a number of sensitivity checks, and is not restricted to locations that are heavier exporters.

Third, we investigate whether the relationship between export sophistication and income per capita growth depends on the trade regime (processing or ordinary) and ownership type (domestic or foreign) of exporting firms. We find that export sophistication in the assembly sector bears no relation to real growth: export upgrading in this sector should therefore not be taken as a signal of Chinese technology adoption, but rather as an artifact due to China's role in the increasing international fragmentation of production. The contribution of assembly exports to the upgrading of China's exports should thus be put to one side for the measurement of the real improvement in the country's level of technology.

More precisely, we find that growth-enhancement is limited to the ordinary export activities of domestic entities: no additional direct benefits pertain from the upgrading of foreign exporters, either in assembly or ordinary exports. This has important implications for China. The country adopted, starting in the early 1980s, a policy of opening to foreign investment, precisely in the hope that technological capabilities and management practices would spill over and bring about greater productivity and export performance and sustain higher growth rates. These policies were believed by many to be the key factor explaining

[4] Their estimated value is almost twice as high as that from the traditional formula in Hummels et al. (2001).

[5] See amongst others Aghion and Howitt (1998), Hausman and Rodrik (2003), Stokey (1988) and Young (1991).

[6] Here and in the rest of the article, we define "foreign firms" as those with some foreign capital ownership: i.e. wholly foreign-owned firms as well as joint ventures (this latter including equity and non-equity joint ventures, and joint cooperatives).

both China's high-end export structure and its rapid growth (Rodrik, 2006). By way of contrast, we find that, even though foreign producers are the main contributors to export upgrading, foreign sophistication appears to have little relation to subsequent growth. The implication is that policies supporting innovation by domestic entrepreneurs may be more efficient in supporting development than FDI promotion.

The remainder of this article is organized as follows. Section 2 presents our measure of export sophistication and the dataset used, and describes the recent evolution of China's export sophistication. Section 3 presents our empirical approach and discusses our results. Last, Section 4 concludes.

## 2. The evolution of the structure of Chinese trade

### 2.1. Measuring export sophistication

We appeal to Hausmann et al. (2007) measure of the sophistication of a country's export basket, obtained by comparison to the income level of countries with similar export structures. In this measure, each good $k$ that a country can potentially produce and export has an intrinsic level of sophistication[7] $PRODY_k$, which is the weighted average of the income levels of good $k$'s exporters, where the weights correspond to the revealed comparative advantage of each country $j$ in good $k$[8]:

$$PRODY_k = \frac{1}{C_k} \sum_j \frac{x_{jk}}{X_j} \times Y_j, \tag{1}$$

Here $x_{jk}$ is the value of exports of good $k$ by country $j$, $X_j$ is the total value of country $j$'s exports and $Y_j$ is per capita income of country $j$, measured as the real GDP per capita in PPP. $C_k$ acts as a normalization so that the coefficients sum to 1. The more good $k$ weighs in the exports of rich countries, the higher is its *PRODY*, the more sophisticated it is considered to be.

The measure aims to avoid the direct determination of the intrinsic product features (the technology embedded in it, the specialized skills required to produce it, R&D investments, and so on). The measure instead infers, from observed patterns of trade, the products which require greater levels of development to be exported.

The sophistication level of country $j$'s exports, denoted by $EXPY_j$, is then computed as the average level of sophistication of its export basket. This is the weighted sum of the sophistication levels associated with each exported good $k$, $PRODY_k$, with the weights being the shares of each good in the country's total exports. This thus reflects the degree of specialization of a country in high-*PRODY* goods.[9]

$$EXPY_{jt} = \sum_k \frac{x_{jkt}}{X_{jt}} PRODY_k. \tag{2}$$

We compute measures of product-level sophistication *PRODY* for 1997[10] using the BACI world trade dataset.[11] This dataset, constructed using COMTRADE original data, provides bilateral trade flows at the 6-digit product level (Gaulier and Zignago, 2010).[12]

We then successively construct the *EXPY* index for the export baskets of China, its international partners and Chinese localities (provinces and prefectures), as in Eq. (2). Our main source here is Chinese customs data, which report region-level exports and imports by 6-digit product over the 1997–2007 period.[13] One feature of interest in this dataset is that it allows us to differentiate between domestic and foreign trading firms, and between processing trade and ordinary trade.[14]

Hausmann et al.'s (2007)*EXPY* measure of sophistication has been criticized on a number of grounds. It has first been argued to be sensitive to the size of the country under consideration (Kumakura, 2007) and the choice of product nomenclature (Yao, 2009). Given these weaknesses, we will use an alternative measure of sophistication (the share of high-technology manufacture in total exports) to check that our results regarding the positive association between export sophistication and subsequent growth are robust. High-technology products are identified via Lall's (2000) classification of products by technological level. The two measures of export sophistication are closely related, as can be seen in Fig. 4. The coefficient of correlation between *EXPY* and the share of high-tech products in exports across Chinese provinces was 61.2% in 1997, varying between 55.1% and 80.3% depending on the sample year.

### 2.2. China's export sophistication

Fig. 1 shows how EXPY varies across countries in 1997. China's sophistication is shown separately for the exports of domestic and foreign firms. This scatterplot of EXPY against per-capita GDP indicates, unsurprisingly given its construction, a similar pattern to that in Rodrik (2006): there is a strong correlation of 0.79 between these two variables in our sample of around 170 countries. Rich (poor) countries export products that tend to be exported by other rich (poor) countries. China is an 'outlier' in this relationship, in terms of both the product bundles exported by domestic and foreign firms. Note that the regression line in Fig. 1 refers to all 170 countries, while only some of these are illustrated in the figure, to avoid swamping it. In 1997, the export bundle of domestic firms was as sophisticated (10,800$) as that of Belarus, a country 2.5 times richer than China in PPP per capita terms; that of foreign firms was higher at 12,500$, similar to that of Portugal, a country eight times richer than China in PPP per capita terms in 1997.

Considering the evolution of China's sophistication over time, distinguishing between domestic and foreign firms, the recent upgrading of China's exports is not confined to foreign entities (which typically operate in processing trade), but also concerns domestic producers. The export sophistication of both types of exporters has risen rapidly. The income level associated with exports by domestic entities increased by 15.5% between 1997 and 2007. Over the same period that of foreign entities however rose even faster, by 25.7%, so that the gap between domestic and foreign export sophistication doubled from 1720$ to 3266$.[15] A similar message comes from the consideration of the share of high-tech products in exports as a measure of export sophistication.

[7] While Hausmann et al. (2007) use the word "productivity" to describe sophistication at the good level, we prefer the terms sophistication, high quality or technological advancement.

[8] The numerator of the weight, $x_{jk}/X_j$, is the value-share of the commodity in country $j$'s overall export basket, while the denominator of the weight, $C_k = \sum_j (x_{jk}/X_j)$, sums the value-shares across all countries exporting the good.

[9] Or, equivalently, the similarity of a given export basket with that of the most-developed countries.

[10] The PRODY indicator is thus calculated with 1997 as reference year, the first year of our sample. This approach reduces the likelihood of any bias in the index. First, it is important to use a consistent sample of countries since non-reporting is likely to be correlated with income. Thus, constructing PRODY for different countries over different years could introduce serious bias into the index. In addition, the choice of 1997 helps to ensure that the index is not affected by the rise of China in international trade (or by any other evolution of world trade structure over the period).

[11] The BACI dataset is downloadable from http://www.cepii.fr/anglaisgraph/bdd/baci.htm. World countries' real GDP per capita in PPP are taken from the World Development Indicators database (World Bank).

[12] The flow dataset is constructed using an original procedure that reconciles the declarations of exporters and importers. The harmonization procedure enables to extend considerably the number of countries for which trade data are available, as compared to the original dataset.

[13] To compute the *EXPY* index for China's trade, the Chinese customs data were converted into the 1992 Harmonized system (HS) classification to match the 1992 classification used in the BACI dataset.

[14] The data also refer to a third ("Others") category that groups other flows such as aid, border trade and consignment. This represents overall less than 1% of total trade value in each year. When we consider the processing/ordinary trade distinction, this category is dropped.

[15] This rise is fully accounted for by the evolution of China's export structure, as the product-level index (PRODY) is computed for 1997 and is thus time-invariant.

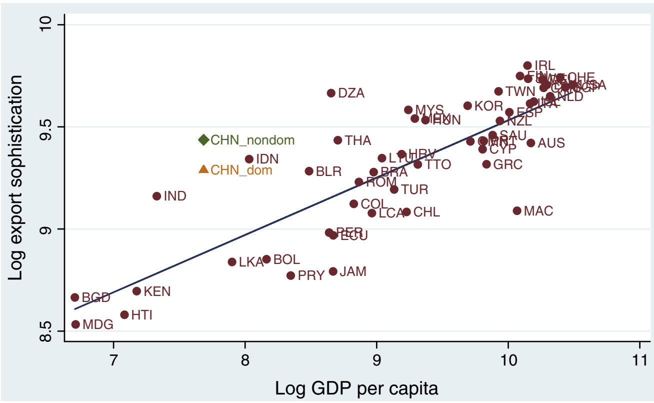


**Fig. 1.** The relationship between per-capita PPP GDP and EXPY (in logs), 1997.
Source: Authors' computations based on BACI and WDI data.

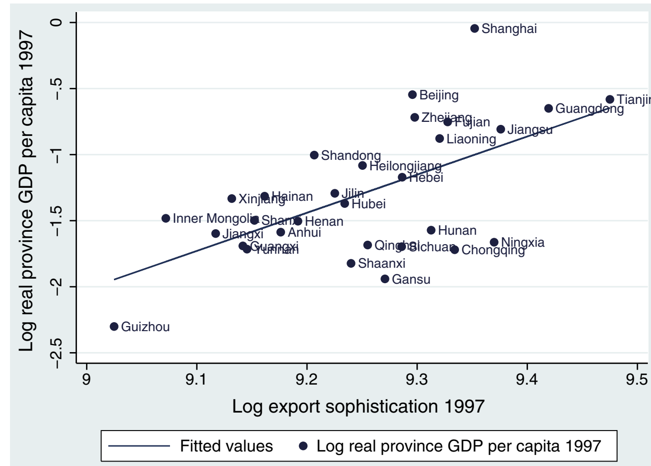


**Fig. 2.** Export sophistication and real GDP per capita, 1997. Note: The slope is 2.89 with a standard error of 0.64.
Source: Authors' computations based on Chinese customs and China Statistical Yearbooks data.

### 2.3. Export sophistication in Chinese provinces

We now analyze the pattern of export sophistication across Chinese provinces. These exhibit considerable variation in industrial structure and overall development, which translate into differences in export structure and sophistication. One important question for our analysis is to know how much of the variance in sophistication is accounted for by different levels of development across provinces.

Fig. 2 shows the relationship between real income per capita (in constant 2000 dollars) and export sophistication across provinces in 1997. The correlation between these two variables in our sample of 30 provinces is positive, with a figure of 0.60 in 1997,[16] which is somewhat lower than that in the cross-country sample (shown in Fig. 1).

Unsurprisingly, the five provinces ranking highest in export sophistication (Tianjin, Guangdong, Jiangsu, Ningxia and Shanghai) are amongst the richest provinces in real GDP per capita terms, with the exception of Ningxia, an interior province (see Fig. 5 for a map of the provinces). This latter province has a high export sophistication score thanks to its relative specialization in a number of sophisticated synthetic chemicals.[17]

Table 1 shows that the provinces where particular policies of international trade and foreign-investment liberalization were put into place exhibit some of the highest levels of export sophistication.

The top five provinces in terms of sophistication include the top two provinces in terms of the number of special policy zones designed to attract foreign investors via tax rebates and subsidies (Guangdong and Jiangsu), as well as the two outward-oriented province-level cities of Shanghai and Tianjin.

In Fig. 3 we consider the relationship between export sophistication in 1997 and real income per capita growth rates between 1997 and 2009 across Chinese provinces, after controlling for initial levels of GDP per capita. The growth residuals are calculated from the regression of real income per capita growth rates between 1997 and 2009 on the log of GDP per capita in 1997. We find a strong correlation here, showing that the link between initial sophistication and subsequent growth does not simply reflect differences in terms of the initial levels of income.

It is worth noting the outlying position of Inner Mongolia. This province reports an average yearly nominal GDP per capita growth rate of 18% between 1997 and 2009, almost twice as high as the national average.[18] We will take this into account via a dummy variable in the empirical estimations.

Fig. 6 presents a similar graph at the prefecture level. This confirms the positive, although weaker, relationship between export sophistication in 1997 and the subsequent real GDP per capita growth rate (1997–2007).

## 3. Empirics

### 3.1. Baseline specification

Our baseline regression models the link between initial export sophistication (*EXPY*) and the subsequent growth rate of real GDP per capita, controlling for initial income and the traditional determinants of economic growth. We follow the specification in Table 8 of Hausmann et al. (2007), modeling a long difference in GDP per capita growth on initial EXPY, initial income and other controls. Our baseline estimations cover 30 provinces over 13 years from 1997 to 2009.

Our baseline regression takes the following form:

$$\frac{y_{i,2009}-y_{i,1997}}{12} = \alpha_0 + \alpha_1 y_{i,1997} + \beta \ln\left(EXPY_{i,1997}\right) + \gamma Inv\,Rate_{i,1997} + \delta HumCap_{i,1997} + \epsilon_i \quad (3)$$

where $y$ denotes log real GDP per capita and $i$ indexes our 30 provinces. The variable *EXPY* is our indicator of export sophistication presented in Section 2. The logarithm of initial real GDP per capita is included to control for convergence across provinces. We also introduce the ratio of investment in fixed assets over GDP (the investment rate) to control for the rate of physical capital accumulation, and the share of population with more than secondary schooling as a proxy for human capital in the provincial workforce (Human Capital). Last, we include a dummy variable for the province of Inner Mongolia, which was identified as an outlier in terms of GDP per capita growth.

Various controls are included to mitigate omitted-variable problems. In the Chinese context, a number of geographical, institutional and political variables are likely to influence simultaneously trade performance and growth trajectories. We introduce dummy variables

[16] This varies between 0.32 and 0.68, depending on the year between 1997 and 2007.

[17] In particular 4.5% of Ningxia's total exports is made up of Cyanoguanidine, a molecule used in fertilizer, of which the most specialized exporters are Norway and Germany. The associated level of income, *PRODY*, for this product is the fifth highest (33,097 PPP $), which helps to explain Ningxia's high level of sophistication.

[18] After taking into account the province-specific rate of inflation and initial GDP per capita, the unexplained growth rate of Inner Mongolia is still almost 5.5%, as can be seen in Fig. 3. We were not able to determine with certainty whether this surprising feature should be attributed to data issues or to a real, unidentified particularity of this province over the period under consideration.

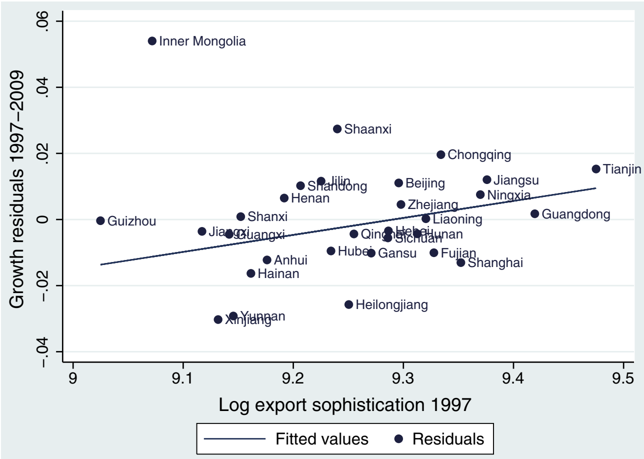


**Fig. 3.** Export sophistication and real GDP per capita growth (1997–2009) across China's provinces after controlling for Ln GDP per capita in 1997. Note: The slope, which is based on the sample excluding Inner Mongolia, is 0.051 with a standard error of 0.022.
Source: Authors' computations based on Chinese customs and China Statistical Yearbooks data.

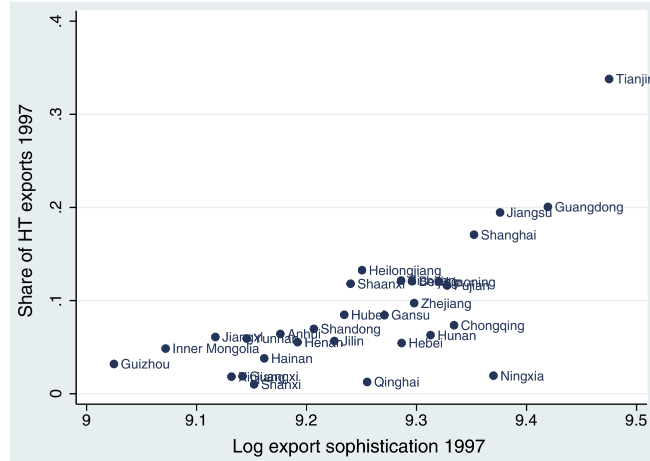


**Fig. 4.** Export sophistication and the share of HT in exports, 1997.
Source: Authors' calculations based on Chinese customs data.

to capture coastal location and the province-level status of the four ‘super cities’ (Beijing, Tianjin, Shanghai and Chongqing). To control for differences in the progress of market-oriented reforms and privatization, we measure the weight of state-owned firms in the economy by their share in total investment (Boyreau-Debray, 2003; Démurger et al., 2002). We also include the number of special policy zones,[19] as computed by Wang and Wei (2010). We finally control for trade openness (imports plus exports over GDP) and FDI inflows (FDI over GDP), as suggested by Barro (1991), Berthélemy and Démurger (2000) and Easterly et al. (1997) in the Chinese context. The summary statistics of all of the variables used in the regressions are displayed in Table A-1 in Appendix A.

We will then check that our results are robust by appealing to a within (fixed-effects) province estimator over three four-year subperiods. As shown in Eq. (4), panel regressions will include both provincial and time dummies, denoted by $\eta_i$ and $\mu_t$ respectively.

$$\frac{y_{i,t+4}-y_{i,t}}{4} = \alpha_0 + \alpha_1 y_{i,t} + \beta \ln\left(EXPY_{i,t}\right) + \gamma InvRate_{i,t} + \delta HumCap_{i,t} + \eta_i + \mu_t + \epsilon_{i,t}. \quad (4)$$

*3.2. Regression results*

*3.2.1. The link between export sophistication and real growth*

*3.2.1.1. Baseline.* Table 2 shows the impact of export sophistication on long-run real GDP per capita growth. Our benchmark growth regression is in Column 1, and Column 2 adds some controls. The control variables attract coefficients with the expected signs. Initial real GDP per capita has a negative and significant coefficient, indicating convergence across Chinese provinces.[20] Our measure of human capital generally enters with a positive and significant coefficient, while that of physical capital accumulation is insignificant. As expected, the openness rate and FDI over GDP attract positive signs, while that on the State share of investment is negative; these coefficients are however not significant. Our main variable of interest, initial export sophistication, attracts a positive and significant coefficient. Provinces whose export structure is more sophisticated achieve higher growth rates over the following 12-year period, conditional on all of the control variables included in the regression. Despite a lower level of significance, our results continue to hold when province-level sophistication is proxied by the share of high-technology products in exports (Column 3).

We can interpret the magnitude of the estimated coefficients in Column 2. Holding other factors constant, a 10% increase in export sophistication (corresponding to the standard deviation divided by the mean, as shown in the summary statistics in Appendix A, Table A-1) raises the average annual real income per capita growth rate over the following 12-year period by about 0.7 percentage points. This figure is of the same order of magnitude as the figure of 0.5 obtained by Hausmann et al. (2007) based on cross-country data over the 1992–2003 period.

As noted above, a number of Chinese provinces are clearly different from the rest, in terms of location and policy particularities which have made them richer, faster-growing, and more open, and more likely to export more sophisticated goods. In Columns 4 to 6, we check whether these results are driven by specific province features. Column 4 adds a dummy variable for the four province-level cities and controls for the number of policy zones. In Columns 5 and 6, we exclude the top three (Guangdong, Shanghai and Jiangsu) and top five (as before plus Shandong and Fujian) exporting provinces, respectively, from the sample; the sample size consequently drops to 27 and 25 respectively. Despite the smaller number of observations, it is striking that the growth elasticity of export sophistication remains significant and of the same size as before, so that the positive relationship between export sophistication and growth is not confined to trade-oriented provinces; even though these are undoubtedly the most important contributors to both the volume and the high-range composition of Chinese exports.

*3.2.1.2. Robustness checks.* The cross-section estimates above suggest a pattern which is robust to the introduction of a number of controls, as well as to the exclusion of the most trade-oriented provinces which seem to summarize best the export sophistication-growth link. There remain two major limitations: the small number of observations, and potential omitted variables, due to our limited capacity to control, in

[19] Such zones were created by the government starting in 1979 in Guangdong, to promote industrial activity, innovation and export activities. They offer low-tax regimes and faster administrative procedures to favor industrial clustering. See column 5 of Table 1.

[20] However, we should acknowledge that the negative coefficient on initial real GDP per capita in Table 2 and subsequent tables may in part reflect measurement error in initial real GDP per capita, as suggested by Barro and Sala-i-Martin (2004). Nevertheless, the finding of convergence across Chinese provinces is in line with much of the empirical literature on regional growth in China (Démurger, 2001; Wang and Yao, 2003).

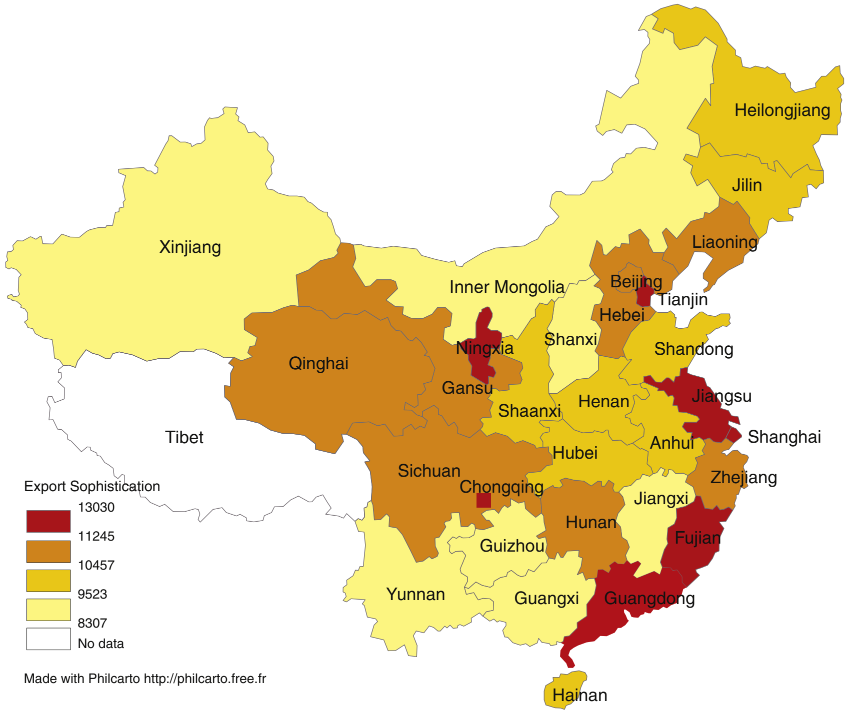


**Fig. 5.** Province-level export sophistication in 1997.
Source: Authors' calculations based on Chinese customs and China Statistical Yearbooks data.

**Table 1**
Summary statistics (by increasing order of sophistication in 1997).

| Province | Sophistication | | Share of high-tech exports | No. of zones | GDP per cap. growth | GDP per cap. in $ | Domestic firms' export share | Share of ordinary exports | Export ratio | Share in China's exports (in %) | Prefectures number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1997 | 2007 | | | | | | | | | |
| Guizhou | 8307 | 8884 | 0.03 | 1 | 0.12 | 265 | 0.86 | 0.76 | 0.05 | 0.2 | 2 |
| Inner Mongolia | 8706 | 11,327 | 0.05 | 1 | 0.18 | 570 | 0.86 | 0.65 | 0.05 | 0.4 | 3 |
| Jiangxi | 9110 | 12,183 | 0.06 | 1 | 0.11 | 499 | 0.93 | 0.88 | 0.05 | 0.6 | 3 |
| Xinjiang | 9243 | 10,000 | 0.02 | 2 | 0.08 | 737 | 0.92 | 0.67 | 0.04 | 0.3 | 1 |
| **Guangxi** | 9338 | 11,411 | 0.02 | 2 | 0.11 | 473 | 0.83 | 0.81 | 0.10 | 1.2 | 7 |
| Yunnan | 9372 | 8958 | 0.06 | 1 | 0.08 | 484 | 0.96 | 0.81 | 0.06 | 0.6 | 2 |
| Shanxi | 9436 | 13,621 | 0.01 | 1 | 0.11 | 568 | 0.90 | 0.78 | 0.06 | 0.6 | 4 |
| Hainan | 9523 | 12,415 | 0.04 | 3 | 0.09 | 665 | 0.88 | 0.81 | 0.16 | 0.4 | 2 |
| Anhui | 9664 | 12,922 | 0.06 | 2 | 0.10 | 526 | 0.87 | 0.70 | 0.05 | 0.8 | 9 |
| Henan | 9816 | 12,150 | 0.06 | 2 | 0.12 | 532 | 0.82 | 0.72 | 0.03 | 0.7 | 12 |
| **Shandong** | 9962 | 12,556 | 0.07 | 6 | 0.12 | 913 | 0.53 | 0.45 | 0.14 | 6.0 | 13 |
| Jilin | 10,150 | 11,024 | 0.06 | 3 | 0.13 | 664 | 0.72 | 0.66 | 0.05 | 0.5 | 6 |
| Hubei | 10,242 | 12,918 | 0.08 | 3 | 0.10 | 709 | 0.83 | 0.67 | 0.05 | 1.1 | 10 |
| Shaanxi | 10,301 | 12,647 | 0.12 | 2 | 0.15 | 439 | 0.90 | 0.80 | 0.08 | 0.7 | 4 |
| Heilongjiang | 10,409 | 9738 | 0.13 | 3 | 0.08 | 871 | 0.79 | 0.57 | 0.04 | 0.7 | 7 |
| Qinghai | 10,457 | 10,667 | 0.01 | 0 | 0.11 | 491 | 0.97 | 0.98 | 0.05 | 0.1 | 1 |
| Gansu | 10,623 | 10,179 | 0.08 | 1 | 0.11 | 378 | 0.90 | 0.82 | 0.04 | 0.2 | 1 |
| Sichuan | 10,786 | 12,819 | 0.12 | 2 | 0.11 | 475 | 0.92 | 0.83 | 0.03 | 0.7 | 6 |
| Hebei | 10,791 | 12,787 | 0.05 | 3 | 0.11 | 731 | 0.80 | 0.81 | 0.07 | 1.8 | 11 |
| Beijing | 10,892 | 15,827 | 0.14 | 2 | 0.12 | 1761 | 0.87 | 0.69 | 0.42 | 5.3 | 1 |
| **Zhejiang** | 10,914 | 13,407 | 0.10 | 4 | 0.11 | 1262 | 0.76 | 0.73 | 0.18 | 5.5 | 10 |
| Hunan | 11,079 | 11,906 | 0.06 | 1 | 0.11 | 558 | 0.92 | 0.88 | 0.04 | 0.8 | 10 |
| **Liaoning** | 11,164 | 12,316 | 0.12 | 5 | 0.11 | 1044 | 0.61 | 0.50 | 0.21 | 5.0 | 13 |
| **Fujian** | 11,245 | 12,820 | 0.12 | 4 | 0.10 | 1103 | 0.48 | 0.39 | 0.28 | 5.6 | 8 |
| Chongqing | 11,317 | 14,436 | 0.07 | 0 | 0.14 | 535 | 0.92 | 0.88 | 0.05 | 0.4 | 1 |
| **Shanghai** | 11,524 | 15,253 | 0.17 | 2 | 0.09 | 2782 | 0.54 | 0.38 | 0.37 | 8.2 | 1 |
| Ningxia | 11,730 | 12,519 | 0.02 | 0 | 0.12 | 480 | 0.83 | 0.86 | 0.07 | 0.1 | 2 |
| **Jiangsu** | 11,800 | 15,594 | 0.20 | 7 | 0.12 | 1127 | 0.52 | 0.47 | 0.17 | 7.7 | 12 |
| **Guangdong** | 12,324 | 14,996 | 0.20 | 10 | 0.11 | 1251 | 0.50 | 0.24 | 0.84 | 40.8 | 18 |
| **Tianjin** | 13,030 | 15,628 | 0.34 | 2 | 0.13 | 1564 | 0.33 | 0.35 | 0.35 | 2.9 | 1 |

Values in 1997 except in Column 2 (2007) and in Column 5 which reports average GDP per capita growth between 1997 and 2007. Provinces in bold are located on the coast. Underlined provinces are those identified as the top five exporting provinces which will be excluded from the sample in Table 2 to verify that the results do not only apply to high-export provinces. The export sophistication value is in 1997 PPP $ per capita. GDP per capita is expressed in dollars. Number of zones: count of the total number of special policy zones located in the province in 1997 (Wang and Wei, 2010). The last column shows the number of prefectures that are used in the prefecture-level regressions in Table 4 and Table 7. See Appendix A for the detailed definition of all variables.

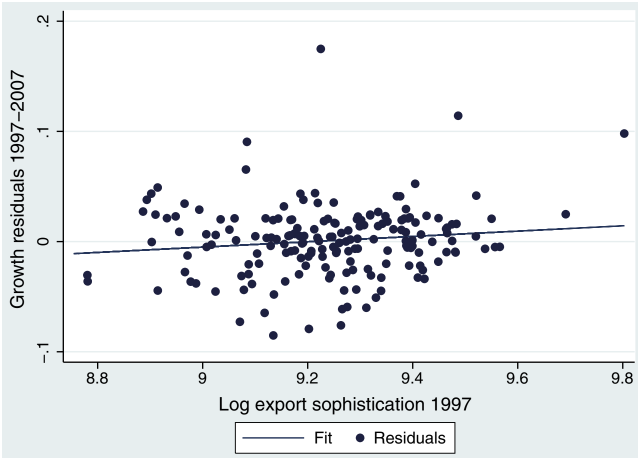


**Fig. 6.** Export sophistication and real GDP per capita growth (1997–2007) across China's prefectures after controlling for Ln GDP per capita in 1997. Note: The regression slope is 0.024 with a standard error of 0.015.
Source: Authors' calculations based on Chinese customs and China Statistical Yearbooks data.

cross-section analysis, for structural differences between Chinese provinces.

We address these issues in turn. We first apply a fixed-effect estimator to our province-level panel dataset. We then consider data at the prefecture level, which is the administrative unit below the province, to produce cross-section estimates on a larger sample. The corresponding results are found in Tables 3 and 4, which follow the same presentation order as Table 2.

Table 3 applies a within (fixed-effects) estimator to a province-level panel covering three four-year sub-periods (1997–2001, 2001–2005 and 2005–2009). The results here confirm that the positive relationship between export sophistication and growth does not just reflect differences in time-invariant variables (such as geography or institutions). The inclusion of time dummies controls for any time-varying variables which are common to all provinces (nation-wide reforms, external demand etc.). The coefficient on sophistication is higher here at 0.15, but does not appear to be significantly different from that in the previous cross-section estimates.

We next estimate Eq. (3) on a cross-section of prefectures, using Customs trade data at the prefecture level for 1997 to calculate sophistication. Combining this with prefecture-level information (GDP, population, investment, and education)[21] for 1997 and 2007 (the most recent year available), we obtain a cross-section of 181 prefectures, covering 90% of China's export value in 1997.[22] Table 4 shows the impact of export sophistication in 1997 on the subsequent 10-year average real GDP per capita growth rate at the prefecture level.

Column 1 shows the benchmark growth regression. Column 2 adds some controls. The investment and openness rates enter positively and significantly, while human capital attracts a positive but insignificant coefficient. The initial level of export sophistication continues to be a positive and significant determinant (although only at the 10% confidence level in some specifications) of the subsequent growth of GDP per capita. Column 3 checks that this positive association is robust to measuring sophistication using Lall's (2000) classification.

Our results are in addition robust to the control and exclusion of the most outwardly-oriented prefectures. Column 4 adds a dummy for prefectures which host a policy zone: this is insignificant and its inclusion does not change our previous findings. Column 5 excludes the top decile of exporting prefectures, while Column 6 drops prefectures hosting a policy zone (based on Wang and Wei, 2010). The positive impact of sophistication remains, confirming that it is not limited to locations with preferential trading and investment policies.

*3.2.2. Decomposition of export sophistication in China*

Our results so far have suggested that specialization in innovative, high-tech products is beneficial, in real growth terms, for both countries and Chinese regions. This would seem at first sight to be an ex post validation of China's industrial and trade policy over the past 30 years, which strongly encouraged export development and supported foreign investment, in the hope of positive technological spillovers. However, the provinces and prefectures which spear-headed these open-door policies – those which were initially chosen by the government to host special economic zones dedicated to export development, and which as a consequence grew into huge investment and export hubs – are seemingly not those where the growth benefits of export upgrading are the most apparent. Controlling for these areas' special features, or alternatively excluding them from the analysis altogether, does not affect our estimates in any significant way.

One possible explanation, as mentioned in our Introduction, is processing trade. When calculating export sophistication we need to account for processing export activities, where the sophistication of exports may not generate growth gains, as it does not reflect the characteristics of the local production, but rather those of imported inputs. We will check this by (1) seeing whether it is the sophistication of imports that is actually driving our results; and (2) distinguishing between trade types and firm-ownership categories. Doing so will allow us to test whether China's unique processing-trade regime systematically upwardly distorts the ‘true’ level of export sophistication. Moreover, this will address the possibility that the positive growth externalities from sophisticated exports are conditional on the trade regime. To see whether they are also conditional on exporting firm types, we will further decompose the total effect of export sophistication on growth into the contributions of domestic and foreign firms, relying on the firm-ownership information in the Customs data.

Tables 5–7 disentangle the roles of trade regime and firm type in the growth-sophistication relationship, for provinces in cross-section and in panel, and in a cross section of prefectures, respectively. Each table proceeds in three steps. We first introduce separately the sophistication level of imports[23] and exports. In the first column of each table, the coefficient on import sophistication is insignificant, while that on export sophistication remains positive and significant, and of the same size as beforehand. Importing sophisticated inputs (or capital goods) does not seem to yield direct gains in growth. This finding is robust to the addition of other control variables (in Column 2 of each table).

In a second step, the next two columns (3 and 4) of each table introduce separate (province or prefecture) export-sophistication

[21] The data are taken from China Data Online provided by the University of Michigan. Unfortunately, the coverage of this database is more limited than the Customs dataset (220 prefectures from 1997 through 2007), which effectively constrains the ultimate sample for the statistical analyses. See Appendix A for definitions of variables and data sources.

[22] They cover the entire Chinese territory. The number of prefectures by province is reported in Table 2.

[23] This is computed analogously to that for exports, by applying the formula in Eq. (2) to the import basket of a given region, yielding the average value of the product-level index *PRODY* in imports, weighted by import shares.

**Table 2**
Cross-section (province): sophistication and real GDP per capita growth 1997–2009.

| Dependent variable | Province real GDP per capita growth 1997–2009 | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | | | No top 3 | No top 5 |
| Initial real GDP per capita | −0.021[b] | −0.043[a] | −0.040[b] | −0.044[a] | −0.043[b] | −0.040[c] |
| | (0.009) | (0.013) | (0.014) | (0.015) | (0.020) | (0.022) |
| Export sophistication | 0.079[b] | 0.074[a] | | 0.063[b] | 0.065[c] | 0.067[c] |
| | (0.030) | (0.025) | | (0.027) | (0.034) | (0.032) |
| Share of HT exports | | | 0.070[c] | | | |
| | | | (0.039) | | | |
| Inner Mongolia | 0.065[a] | 0.069[a] | 0.058[a] | 0.070[a] | 0.070[a] | 0.069[a] |
| | (0.006) | (0.007) | (0.007) | (0.007) | (0.009) | (0.009) |
| Investment rate | −0.004 | 0.002 | 0.004 | 0.001 | 0.002 | 0.005 |
| | (0.011) | (0.014) | (0.015) | (0.017) | (0.019) | (0.020) |
| Human capital | 0.022 | 0.035[b] | 0.037[c] | 0.031[c] | 0.029 | 0.032 |
| | (0.014) | (0.015) | (0.019) | (0.017) | (0.018) | (0.025) |
| Coastal province dummy | | 0.010 | 0.010 | 0.012 | 0.008 | 0.008 |
| | | (0.009) | (0.010) | (0.009) | (0.009) | (0.009) |
| Openness rate | | 0.005 | 0.005 | 0.001 | 0.003 | 0.002 |
| | | (0.005) | (0.005) | (0.006) | (0.007) | (0.008) |
| FDI over GDP | | 0.001 | −0.001 | 0.001 | 0.000 | 0.002 |
| | | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Share of state in investment | | −0.010 | −0.014 | −0.005 | −0.007 | −0.006 |
| | | (0.012) | (0.016) | (0.013) | (0.014) | (0.017) |
| Province-level city dummy | | | | 0.013 | 0.015[c] | 0.009 |
| | | | | (0.008) | (0.009) | (0.013) |
| Number of policy zones | | | | 0.002 | 0.003 | −0.001 |
| | | | | (0.002) | (0.003) | (0.004) |
| Observations | 30 | 30 | 30 | 30 | 27 | 25 |
| $R^2$ | 0.551 | 0.669 | 0.598 | 0.687 | 0.687 | 0.707 |

Heteroskedasticity-robust standard errors are shown in parentheses: [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence level. Column 5 reports the results without the three main exporters (Guangdong, Shanghai and Jiangsu), and Column 6 further excludes Shandong and Fujian. The values of the control variables refer to the beginning of the sample period.

indices (*EXPY*) for the processing and ordinary export baskets. We also control for the share of ordinary trade in the total export value of the region. We obtain, in each case, a positive and significant coefficient only for the ordinary component of trade, while processing exports sophistication is not correlated with growth.

The third step further decomposes export sophistication by trade regime and firm ownership. In Columns 5 and 6 of each table, foreign-firm export sophistication is decomposed into its processing and ordinary components. We thus test if foreign sophistication whether in ordinary or processing has an effect on subsequent economic

**Table 3**
Within regressions (province): sophistication and real GDP per capita growth between 1997 and 2009 (3× 4-year sub-periods).

| Explained variable | Province real GDP per capita growth 1997–2009, (3× 4-year sub-periods) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | | | No top 3 | No top 5 |
| Initial real GDP per capita | −0.139[a] | −0.135[a] | −0.119[a] | −0.132[a] | −0.134[a] | −0.129[a] |
| | (0.036) | (0.038) | (0.040) | (0.037) | (0.037) | (0.038) |
| Export sophistication | 0.150[a] | 0.144[b] | | 0.150[b] | 0.155[b] | 0.157[b] |
| | (0.050) | (0.055) | | (0.067) | (0.069) | (0.071) |
| Share of HT exports | | | 0.084[c] | | | |
| | | | (0.044) | | | |
| Investment rate | 0.076[a] | 0.075[a] | 0.080[a] | 0.075[a] | 0.084[a] | 0.086[a] |
| | (0.012) | (0.011) | (0.014) | (0.012) | (0.014) | (0.013) |
| Human capital | 0.088[c] | 0.070 | 0.054 | 0.080 | 0.103 | 0.118 |
| | (0.045) | (0.057) | (0.056) | (0.077) | (0.079) | (0.086) |
| Openness rate | | −0.006 | −0.009 | −0.004 | −0.003 | −0.004 |
| | | (0.009) | (0.009) | (0.014) | (0.015) | (0.016) |
| FDI over GDP | | 0.000 | 0.000 | −0.000 | −0.001 | −0.001 |
| | | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) |
| Share of state in investment | | 0.013 | 0.018 | 0.012 | 0.009 | 0.001 |
| | | (0.019) | (0.018) | (0.020) | (0.021) | (0.023) |
| Number of policy zones | | | | −0.001 | −0.001 | −0.002 |
| | | | | (0.004) | (0.005) | (0.006) |
| Fixed effects | Province fixed effects and year fixed effects | | | | | |
| Observations | 90 | 90 | 90 | 90 | 81 | 75 |
| $R^2$ | 0.807 | 0.811 | 0.785 | 0.812 | 0.816 | 0.820 |

Heteroskedasticity-robust standard errors are shown in parentheses. Standard errors are clustered at the province level. [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence level. Column 5 reports the results without the three main exporters (Guangdong, Shanghai and Jiangsu), and Column 6 further excludes Shandong and Fujian. The values of the control variables refer to the beginning of the 4-year period.

**Table 4**
Cross-section (prefecture): sophistication and real GDP per capita growth 1997–2007.

| Explained variable | Prefectures real GDP per capita growth 1997–2007 | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | | | No top decile | No policy zone |
| Initial real GDP per capita | −0.004 | −0.013[c] | −0.011[c] | −0.012[c] | −0.013[c] | −0.015[c] |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.009) |
| Export sophistication | 0.028[c] | 0.030[b] | | 0.030[b] | 0.025[c] | 0.031[c] |
| | (0.016) | (0.015) | | (0.015) | (0.015) | (0.016) |
| Share of HT exports | | | 0.029[c] | | | |
| | | | (0.016) | | | |
| Investment rate | 0.019[b] | 0.016[b] | 0.015[b] | 0.016[b] | 0.017[a] | 0.027[a] |
| | (0.008) | (0.007) | (0.007) | (0.007) | (0.006) | (0.008) |
| Human capital | 0.000 | −0.004 | −0.004 | −0.003 | −0.007 | 0.014 |
| | (0.005) | (0.005) | (0.005) | (0.006) | (0.007) | (0.021) |
| Province-level city dummy | | −0.009 | −0.007 | −0.009 | −0.015[c] | −0.010 |
| | | (0.008) | (0.008) | (0.008) | (0.009) | (0.008) |
| Openness rate | | 0.009[a] | 0.009[a] | 0.009[a] | 0.010[a] | 0.010[a] |
| | | (0.003) | (0.003) | (0.003) | (0.002) | (0.003) |
| FDI over GDP | | −0.003 | −0.003 | −0.003 | −0.003 | −0.003 |
| | | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Policy zone dummy | | | | −0.002 | 0.001 | n.a. |
| | | | | (0.008) | (0.007) | n.a. |
| Observations | 181 | 181 | 181 | 181 | 163 | 125 |
| $R^2$ | 0.094 | 0.192 | 0.178 | 0.192 | 0.247 | 0.322 |

Heteroskedasticity-robust standard errors are shown in parentheses: [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels. The values of the control variables refer to the beginning of the sample period. Column 5 reports the results without the top decile of exporting prefectures, and Column 6 shows the results estimated only on prefectures with no policy zones.

**Table 5**
Decomposing export sophistication: cross-section (provinces).

| Dependent variable | Province real GDP per capita growth 1997–2007 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Initial real GDP per capita | −0.034[b] | −0.036[b] | −0.036[b] | −0.036[b] | −0.037[c] | −0.039 | −0.037[c] | −0.040 |
| | (0.013) | (0.015) | (0.015) | (0.017) | (0.018) | (0.023) | (0.018) | (0.024) |
| Export sophistication | 0.074[b] | 0.063[b] | | | | | | |
| | (0.027) | (0.029) | | | | | | |
| Import sophistication | 0.008 | −0.001 | | | | | | |
| | (0.023) | (0.030) | | | | | | |
| Ordinary export sophistication | | | 0.091[a] | 0.080[b] | | | | |
| | | | (0.030) | (0.028) | | | | |
| Processing export sophistication | | | −0.009 | −0.016 | | | | |
| | | | (0.016) | (0.015) | | | | |
| Share of ordinary trade in exports | | | −0.005 | 0.001 | −0.003 | 0.002 | −0.004 | 0.001 |
| | | | (0.014) | (0.017) | (0.019) | (0.023) | (0.016) | (0.024) |
| Domestic export sophistication | | | | | 0.074[c] | 0.077[b] | | |
| | | | | | (0.039) | (0.036) | | |
| Domestic ordinary | | | | | | | 0.079[b] | 0.075[b] |
| | | | | | | | (0.035) | (0.031) |
| Domestic processing | | | | | | | −0.013 | −0.011 |
| | | | | | | | (0.022) | (0.022) |
| Export sophistication | | | | | | | | |
| Foreign ordinary | | | | | 0.010 | 0.002 | 0.006 | 0.002 |
| | | | | | (0.018) | (0.019) | (0.018) | (0.021) |
| Foreign processing | | | | | −0.002 | −0.016 | 0.004 | −0.007 |
| | | | | | (0.024) | (0.024) | (0.022) | (0.025) |
| Investment rate | −0.005 | −0.001 | −0.006 | 0.001 | −0.013 | −0.009 | −0.009 | −0.002 |
| | (0.012) | (0.017) | (0.011) | (0.018) | (0.013) | (0.018) | (0.012) | (0.018) |
| Human capital | 0.025 | 0.022 | 0.019 | 0.012 | 0.037[c] | 0.033 | 0.023 | 0.021 |
| | (0.015) | (0.016) | (0.016) | (0.015) | (0.020) | (0.019) | (0.024) | (0.023) |
| Openness rate | 0.007 | 0.002 | 0.011[b] | 0.004 | 0.010[c] | 0.002 | 0.012[b] | 0.005 |
| | (0.004) | (0.005) | (0.005) | (0.006) | (0.005) | (0.005) | (0.005) | (0.007) |
| FDI over GDP | | 0.001 | | 0.002 | | 0.002 | | 0.003 |
| | | (0.005) | | (0.004) | | (0.005) | | (0.005) |
| Inner Mongolia | 0.068[a] | 0.069[a] | 0.067[a] | 0.072[a] | 0.064[a] | 0.069[a] | 0.068[a] | 0.073[a] |
| | (0.007) | (0.008) | (0.006) | (0.007) | (0.007) | (0.008) | (0.008) | (0.008) |
| Number of policy zones | | 0.002 | | 0.003[c] | | 0.003 | | 0.003 |
| | | (0.002) | | (0.002) | | (0.002) | | (0.002) |
| Province-level city dummy | | 0.015 | | 0.020[b] | | 0.024[c] | | 0.021[c] |
| | | (0.011) | | (0.008) | | (0.012) | | (0.010) |
| Observations | 30 | 30 | 30 | 30 | 29 | 29 | 29 | 29 |
| $R^2$ | 0.613 | 0.641 | 0.654 | 0.707 | 0.641 | 0.707 | 0.680 | 0.736 |

Heteroskedasticity-robust standard errors are shown in parentheses: [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels respectively. All of the control variables refer to the beginning of the sample period.

**Table 6**
Decomposing export sophistication: panel fixed-effect regressions on provinces (3× 4-year sub-periods).

| Explained variable | Province real GDP per capita growth 1997–2009, (3× 4-year sub-periods) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Initial real GDP per capita | −0.141[a] | −0.137[a] | −0.123[a] | −0.120[a] | −0.130[a] | −0.122[a] | −0.124[a] | −0.115[a] |
| | (0.036) | (0.035) | (0.032) | (0.033) | (0.029) | (0.028) | (0.027) | (0.027) |
| Export sophistication | 0.147[a] | 0.155[b] | | | | | | |
| | (0.053) | (0.061) | | | | | | |
| Import sophistication | 0.005 | 0.007 | | | | | | |
| | (0.012) | (0.014) | | | | | | |
| Ordinary export sophistication | | | 0.082[c] | 0.086[c] | | | | |
| | | | (0.045) | (0.048) | | | | |
| Processing export sophistication | | | 0.019 | 0.019 | | | | |
| | | | (0.018) | (0.018) | | | | |
| Share of ordinary trade in exports | | | 0.052[a] | 0.054[a] | 0.045[a] | 0.047[a] | 0.062[a] | 0.066[a] |
| | | | (0.012) | (0.013) | (0.008) | (0.008) | (0.012) | (0.013) |
| Domestic export sophistication | | | | | 0.120[b] | 0.131[a] | | |
| | | | | | (0.046) | (0.047) | | |
| Domestic ordinary | | | | | | | 0.094[b] | 0.103[b] |
| | | | | | | | (0.041) | (0.045) |
| Domestic processing | | | | | | | −0.009 | −0.011 |
| | | | | | | | (0.013) | (0.014) |
| Export sophistication | | | | | | | | |
| Foreign ordinary | | | | | 0.031 | 0.034 | 0.023 | 0.026 |
| | | | | | (0.024) | (0.024) | (0.023) | (0.022) |
| Foreign processing | | | | | 0.021 | 0.019 | 0.032 | 0.034 |
| | | | | | (0.028) | (0.027) | (0.029) | (0.029) |
| Investment rate | 0.076[a] | 0.078[a] | 0.065[a] | 0.064[a] | 0.067[a] | 0.066[a] | 0.072[a] | 0.076[a] |
| | (0.012) | (0.012) | (0.010) | (0.010) | (0.009) | (0.009) | (0.010) | (0.011) |
| Human capital | 0.081 | 0.094 | 0.119[a] | 0.126[b] | 0.122[b] | 0.151[b] | 0.098 | 0.114 |
| | (0.049) | (0.070) | (0.042) | (0.059) | (0.050) | (0.065) | (0.059) | (0.075) |
| Openness rate | −0.006 | −0.003 | 0.007 | 0.009 | 0.009 | 0.015 | 0.014 | 0.020 |
| | (0.009) | (0.015) | (0.009) | (0.013) | (0.009) | (0.011) | (0.010) | (0.014) |
| FDI over GDP | | −0.001 | | 0.001 | | 0.001 | | −0.003 |
| | | (0.003) | | (0.002) | | (0.004) | | (0.004) |
| Number of policy zones | | −0.002 | | −0.002 | | −0.003 | | −0.003 |
| | | (0.004) | | (0.003) | | (0.003) | | (0.003) |
| Fixed effects | Province fixed effects and year fixed effects | | | | | | | |
| Observations | 90 | 90 | 90 | 90 | 88 | 88 | 88 | 88 |
| $R^2$ | 0.809 | 0.810 | 0.831 | 0.832 | 0.851 | 0.855 | 0.847 | 0.850 |

Heteroskedasticity-robust standard errors are shown in parentheses. Standard errors are clustered at the province level. [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels. All of the control variables refer to the beginning of the sample period.

growth. Finally, in the last two columns (7 and 8), export sophistication is split into its four components of processing and ordinary trade, separately for domestic and foreign entities.[24]

The results consistently show that the sophistication of foreign firms' exports has no direct impact on growth, even when distinguishing exports by assembly/ordinary sector. The upgrading of production capabilities by foreign producers does not then generate positive externalities, even when they use China for ordinary trade and produce the major part of their value-added there. The growth premium seems to be generated exclusively by domestic firms, operating in the ordinary trade regime.

These findings bring new light to the so-called sophistication debate regarding China. A number of pieces of work have suggested that export sophistication in China is closely linked to the assembly-trade sector and the presence of foreign firms (Wang and Wei, 2010; Xu and Lu, 2009). Our results are entirely consistent with this pattern, as shown by the casual observation of province-level statistics on export sophistication and structure (see Table 1). The main driver of China's export sophistication between 1997 and 2007, accounting for 75% of the rise, is upgrading in processing trade from foreign firms. We show, however, that the increase in and upgrading of processing exports may not have generated growth benefits. Decomposing China's export sophistication by trade regime and firm type reveals that the highest export growth and greatest upgrading did not coincide with the highest growth benefits. Only upgrading of ordinary exports by domestic firms is positively and significantly associated with subsequent economic growth, despite its limited role in the rise in Chinese overall export sophistication. This is consistent with Koopmans et al. (2008), who find that exports from domestic firms embody the greatest domestic value-added share; wholly foreign-owned firms have the lowest share of domestic value-added (28% compared to 82% for private domestic firms in 2006). They note that the share of domestic content is negatively correlated with reliance on processing exports.

In this sense, we are in line with the literature arguing that processing and ordinary trade cannot be mixed together. Our results suggest that these two differ intrinsically with respect to their characteristics and their potential benefits. Ordinary export sophistication seems to reflect genuine technology adoption and capacity building, in contrast to processing-export sophistication. Trade regimes and firm types therefore need to be distinguished with respect to the growth implications of technological progress.

It should be noted however that we do not think that the absence of a direct effect of foreign firms' export sophistication on economic growth, once that of domestic firms is taken into account, proves that foreign-owned firms, or even processing trade, has no positive growth impact at all. The rationale behind China's FDI attraction policy was the hope of spillovers from foreign-owned to domestic firms. That the upgrading of domestic firms' exports, which has positive growth effects, comes about

[24] By doing so we lose some observations, due to the absence of some export categories in some regions. In the province-level sample, Qinghai is dropped when foreign export sophistication is split into processing and ordinary trade, as in 1997 no foreign firm operated in processing trade there. The number of observations is lower in Tables 6 and 7 for similar reasons.

**Table 7**
Decomposing export sophistication: cross-section (prefectures).

| Explained variable | Prefecture real GDP per capita growth 1997–2007 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Initial real GDP per capita | −0.014[c] | −0.012[c] | −0.014[b] | −0.012[c] | −0.013[c] | −0.010 | −0.013[c] | −0.010 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Export sophistication | 0.029[c] | 0.030[b] | | | | | | |
| | (0.015) | (0.015) | | | | | | |
| Import sophistication | −0.001 | 0.000 | | | | | | |
| | (0.009) | (0.009) | | | | | | |
| Ordinary export sophistication | | | 0.046[a] | 0.047[a] | | | | |
| | | | (0.015) | (0.014) | | | | |
| Processing export sophistication | | | −0.005 | −0.003 | | | | |
| | | | (0.010) | (0.010) | | | | |
| Share of ordinary trade in exports | | | 0.001 | 0.001 | −0.001 | −0.001 | 0.001 | 0.001 |
| | | | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Domestic export sophistication | | | | | 0.034[b] | 0.035[b] | | |
| | | | | | (0.015) | (0.014) | | |
| Domestic ordinary | | | | | | | 0.041[a] | 0.042[a] |
| | | | | | | | (0.014) | (0.013) |
| Domestic processing | | | | | | | −0.006 | −0.005 |
| | | | | | | | (0.008) | (0.008) |
| Export sophistication | | | | | | | | |
| Foreign ordinary | | | | | 0.001 | −0.001 | −0.005 | −0.006 |
| | | | | | (0.010) | (0.010) | (0.010) | (0.011) |
| Foreign processing | | | | | −0.010 | −0.008 | −0.008 | −0.005 |
| | | | | | (0.008) | (0.008) | (0.009) | (0.009) |
| Investment rate | 0.016[b] | 0.016[b] | 0.015[b] | 0.015[b] | 0.016[b] | 0.015[b] | 0.016[b] | 0.016[b] |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.008) | (0.007) | (0.008) | (0.008) |
| Human capital | −0.004 | −0.003 | −0.005 | −0.003 | −0.004 | −0.002 | −0.005 | −0.002 |
| | (0.005) | (0.006) | (0.005) | (0.006) | (0.005) | (0.006) | (0.006) | (0.007) |
| Openness rate | 0.007[a] | 0.009[a] | 0.009[a] | 0.010[a] | 0.007[a] | 0.009[a] | 0.008[a] | 0.010[a] |
| | (0.002) | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| FDI over GDP | | −0.003 | | −0.003 | | −0.004 | | −0.004 |
| | | (0.002) | | (0.002) | | (0.002) | | (0.003) |
| Policy zone dummy | | −0.002 | | −0.003 | | −0.004 | | −0.006 |
| | | (0.008) | | (0.008) | | (0.008) | | (0.008) |
| Province-level city dummy | | −0.009 | | −0.008 | | −0.005 | | −0.005 |
| | | (0.008) | | (0.009) | | (0.009) | | (0.009) |
| Observations | 181 | 181 | 176 | 176 | 172 | 172 | 159 | 159 |
| $R^2$ | 0.178 | 0.192 | 0.196 | 0.209 | 0.179 | 0.198 | 0.175 | 0.198 |

Heteroskedasticity-robust standard errors are shown in parentheses. [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels. All of the control variables refer to the beginning of the sample period.

due to such spillovers, is a possibility that we have not examined here. While some recent work has found only little evidence of such technological spillovers in China (e.g. Bloningen and Ma (2007)), there may still be room for indirect effects of foreign on domestic firms via emulation or export spillovers, as suggested by Mayneris and Poncet (2010). These results together with ours do call for more research on the real growth benefits of China's foreign investment policy.

## 4. Conclusion

We have here carried out a test of Hausmann et al. (2007) prediction that regions which develop more sophisticated goods subsequently grow faster, using regional variations within a single country (China). We find that, even at the province and prefecture level, there is considerable variation in export sophistication, controlling for the level of development, and that this variation in turn matters for growth. We find however that the growth gains from improved technology only come about when the latter is developed by domestic-owned firms and embedded in ordinary trade. This suggests that the different sources (export regime and firm type) of Chinese export upgrading must be distinguished for the true measurement of the improvement in technology and its implications for economic growth. In this respect, fruitful avenues for further research include the identification of the sectors which contribute to export sophistication, as well as the potential links between particular sectors with rising sophistication in different provinces and provincial regulations and export promotion activities.

## Appendix A. Variable definitions and statistical sources

Macro-level data at the provincial and prefecture level (GDP, investment, and human capital) are taken from China Data Online, provided by the University of Michigan.

*Dependent variable*

GDP per capita: logarithm of real GDP per capita (deflated by annual CPI).

*Explanatory variables*

*Sophistication*

Export sophistication is measured by the logarithm of *EXPY* as defined in Eq. (2). This is computed based on trade flows from the China Customs database. Measures based on domestic (foreign) firms only are referred to as domestic (foreign) export sophistication: measures based on ordinary (processing) trade flows only are referred to as ordinary (processing) export sophistication. We also use the share of high-tech products in exports (as defined by Lall (2000)).

*Other control variables*

*Investment rate:* the logarithm of the share of gross fixed investment in GDP.

*Human capital:* the province-level variable is the logarithm of the share of population aged 6 and over declaring educational attainment of secondary level or above. This is a stock measure of higher-education attainment. It is computed using data collected in the yearly national sample survey on population change, as the sum of people who have attained the junior secondary, senior secondary or college and higher levels. Since these data are not available at the prefecture level, we there appeal to the ratio of student enrollment in regular secondary schools to the total population.

*Share of state in investment:* the logarithm of the share of state entities in total investment in fixed assets.

*Openness rate:* the logarithm of the ratio of exports plus imports to GDP.

*FDI over GDP rate:* the logarithm of the ratio of foreign direct investment inflows to GDP.

*Policy zone:* we here construct two measures using the description of policy zones (special economic zones, economic and technological development zones, high-tech industrial zones, and export-processing zones) at the prefecture level (which varies over time) developed by Wang and Wei (2010). At the prefecture level, we construct an economic zone dummy for the prefecture hosting a policy zone in 1997. At the province level, we construct a time-varying measure of the number of policy zones in the province.

*Coastal province dummy:* This equals one when the location lies on the coast (i.e. Fujian, Guangdong, Guangxi, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang).

**Table A-1**
Summary statistics at the province level.

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Average growth rate 1997–2007 | 0.113 | 0.019 | 0.080 | 0.176 |
| Initial real GDP per capita ($) | 0.310 | 0.180 | 0.100 | 0.956 |
| Export sophistication (1997 PPP $) | 10,442 | 1088 | 8307 | 13,030 |
| Share of high-tech exports | 0.09 | 0.07 | 0.01 | 0.34 |
| Investment rate | 0.333 | 0.088 | 0.224 | 0.589 |
| Human capital | 0.467 | 0.105 | 0.242 | 0.702 |
| Openness rate | 0.261 | 0.365 | 0.038 | 1.464 |
| FDI over GDP | 0.041 | 0.046 | 0.001 | 0.169 |
| Share of state in investment | 0.607 | 0.148 | 0.375 | 0.863 |
| Number of policy zones | 2.533 | 2.177 | 0 | 10 |

The table shows the average value over the 30 provinces in 1997. See Appendix A for precise definitions of all variables.

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