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*Does High-tech Export Cause More Technology Spillover?
Evidence from Contemporary China*

By

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Abstract:

This paper attempts to investigate whether high-tech product export causes more technology spillover compared with traditionally primary manufactured goods export. A generalized multi-sector spillover model is presented to involve the causations of export composition and technology spillover, which is based on two distinctive approaches of measuring technology spillover: “between-spillover” and “within-spillover”. The empirical estimation is conducted with a panel analysis involving 31 provinces in China over the period of 1998-2005. Although high-tech export sectors involve a higher productivity compared with other sectors, this productivity advantage in high-tech export sectors does not cause technology spillover towards both domestic sectors and other export sectors. Therefore, this paper suggests that technology spillover of export mainly takes place in traditional export sectors rather than high-tech export sectors.

JEL Classification Number: F10, O24, O41

Keywords: Export Composition; High-tech Export; Technology Spillover; Multi-sector Spillover Model

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Non-Technical Summary

China's high-tech product export has experienced a sharply growth period since the implementation of its export promotion strategy "Revitalizing the Trade through Science and Technology" in 1999. This paper attempts to investigate whether high-tech product export causes more technology spillover compared with traditionally primary manufactured goods export. In the theoretical parts, this paper presents a generalized multi-sector spillover model involving the causations of export composition and technology spillover, where two distinctive approaches of measuring technology spillover are identified: "between-spillover" refers to technology spillover of various export sectors towards indigenous firms; "within-spillover" means technology spillover of high-tech export towards other traditional export sectors. The empirical estimation is conducted based on a panel analysis involving all provinces in China in the recent decades. According to the results, although high-tech export sectors involve a higher productivity compared with other sectors, this productivity advantage in high-tech export sectors does not cause technology spillover towards both domestic sectors and other export sectors. Therefore, this paper suggests that technology spillover of export mainly takes place in traditional export sectors rather than high-tech export sectors. As such empirical findings can be largely attributed to the fact that China's high-tech product export highly depends on processing trade by foreign-invested firms, policy implication is also provided regarding how to promote the role of China's high-tech export in its economic growth.

The first section is an introduction of this paper, and the following section briefly reviews the literature on export and economic growth. The third section sets forth our generalized multi-sector spillover model. In the fourth section the empirical estimations are conducted through our specified econometric models based on China's panel data of 31 provinces. The following two sections explain between-spillover and within-spillover effects of high-tech products export respectively. Finally we provide a conclusion and policy implication for this paper.

1. Introduction

While China has experienced rapid export growth during the past decades, its export structure has also shown a substantial shift towards manufacturing goods, in particular high-tech goods export. As illustrated in table one, China's high-tech goods export has grown annually at a higher rate than its total export, and the share of high-tech goods export maintains an increasing trend. For example, in 1998 high-tech goods export only accounts for 13.72 percent of China's total export, very closed to that of primary goods export in China. However, while the share of primary goods export sharply decreases to 5.05 percent in 2007, the share of high-tech goods export in both the total export and manufactured goods export has notably risen to 28.61 percent and 30.08 percent respectively in that year. China's role in global high-tech goods market has also been increasingly significant. In 1995, China only accounts for 2.1% of global high-tech exports, representing in real terms around 8% of the US trade value. However, in 2006, China has surpassed the US and the EU-27 to emerge as the largest high-tech exporting country with 16.9% of global market share in high-tech products.

[Insert table one]

Such profound adjustment of China's export composition demonstrates that the implementation of Strategy of "Revitalizing the Trade through Science and Technology" in China since 1999 has been a successful measure to promote China's export of high-tech products. Being an important part of China's national development strategy "Revitalizing China through Science and Technology", this export promotion policy is jointly implemented by the Ministry of Commerce, the Ministry of Science and Technology, the National Development and Reform Commission etc., which aims at transforming and updating China's export pattern through various measures, such as constructing export innovation base, increasing the competitiveness of export-oriented enterprises, improving the quality and value-added of export goods etc. The rapid shift of China's export composition has also attracted increasing attention with reference to its export quality and technology sophistication recently. It is Rodrik (2006) who first sets an index of so-called technology sophistication to measure a country's overall export sophistication level, which links product sophistication level to income levels of exporting countries. Rodrik reveals that China's overall export sophistication level is exceptionally higher than it should be, and hence concludes that China is an outlier in terms of the overall sophistication of its exports¹. Schott

¹ Although the index of export sophistication level in Rodrik (2006) is widely cited, the author's conclusion "China-is-special" is challenged by others. For example, in a direct response to Rodrik's work, Kumakura (2007)

(2006) also indicates that China's export similarity index with the OECD countries is on average 0.39 and 0.27 higher than for countries with similar GDP per capita and skill abundance, respectively. Therefore, in order to understand the role of exports in China's economic growth, we need investigate not only China's total export development, but also the consequence of China's export composition change.

While it's widely acknowledged that export and trade openness play a significant contribution to China's rapid economic growth since its reform in 1978 (Chen and Feng, 2000; Jin, 2004; Yao, 2006), the growth effect of export composition has been less considered, in particular the role of China's high-tech goods export in its economic development. Although China's high-tech goods export itself has experienced remarkable growth, what's the economic consequence of such phenomenon? In other words, how does China's export composition shift affect its economic growth? Since the principal purpose of China's strategy "Revitalizing China through Science and Technology" is not only promoting high-tech goods export itself, but also rejuvenating its traditional export through fostering high-tech export, we are interested to know whether high-tech export causes technology spillover towards China's traditional export sectors. Furthermore, it's meaningful to investigate whether China's domestic sectors and indigenous firms also benefit from its high-tech goods export through various channels of technology demonstration and spillover, industrial linkage etc. Based on a multi-sector spillover model, we adopt China's panel data of 31 provinces to examine whether there is significant technology spillover effect of high-tech export in China. Our study here helps to not only understand the economic consequence of China's rapid development of high-tech export, but also comprehensively evaluate the policy outcome of China's export promotion strategy in recent years.

We proceed as follows. Section 2 briefly reviews the literature on export and economic growth. Section 3 sets forth our generalized multi-sector spillover model. In Section 4, the empirical estimations are conducted through our specified econometric models based on China's panel data of 31 provinces. Section 5 and 6 explain between-spillover and within-spillover effects of high-tech products export respectively. Section 7 provides a conclusion and policy implication for this paper.

points out that the accuracy of his empirical analysis is questionable. Xu (2006) also emphasizes that Roridk (2006) tends to overestimate the technology sophistication level of China's export since the author doesn't consider product quality. Using unit-value differences as a proxy for quality differences in constructing a quality adjusted index of export sophistication, Xu (2006) finds that the Rodrik's China-is-special result is weakened by 10 to 30 percent.

2. Literature Review

The interrelationship between exports and economic growth has been a subject of much interest in the literatures about development and growth. The arguments in favor of openness are well known and can date back to studies by Adam Smith about market specialization. The long-run growth effects are added into latest growth models when the areas of specialization promoted by trade enjoy increasing returns to scale and technology spillovers in the endogenous growth models (Young 1991, Grossman and Helpman 1991, and Romer 1993). Romer (1993) shows that once the less developed countries open up to the foreign countries with more advanced technology, they could increase in both the rate of innovation and the then growth rate of economic development. According to studies by Grossman and Helpman (1991), the knowledge spillovers are resulted from trade openness and the ability to imitate as engines of endogenous growth.

A large number of empirical studies have also examined the impacts of export on economic growth, and in general the estimation results confirm the positive effects of export on economic growth, such as Levin and Raut (1997), Miller and Upadhyay (2002), Lee and Huang (2002) and Konya (2006). Most of these literatures concentrate on total trade volume of exports, however, the impacts of exports composition economic growth are in fact less considered. Fosu (1990) studies the effects of manufacturing exports on growth for developing countries as compared to primary sector exports, and concludes that there is a differential positive impact by the manufacturing export sector. Based on empirical studies in Malaysia during 1955-1990, Ghatak et al. (1997) concludes that the export-led growth hypothesis is driven by the relative importance of non-traditional exports in the total exports. According to the study by Herzer et al. (2006), Chile's manufactured goods export significantly helps to improve the total factor productivity, while it is not true for its primary goods export. While those above studies all reveal that manufactured goods export play a much more important role in promoting economic growth and productivity efficiency than primary goods export, however, there are also others who support the importance of the latter. For example, in their structural analysis of different export sectors and their possible relationship with the Spanish economic growth, Balaguer and Cantavella (2004) shows that during 1961-2000 there is some feedback effects between economic growth and primary export activities such as food and consumption came about. Some authors focus their study on industries level analysis. Greenaway et al. (1999) points out that some specific industries like fuel, metals and

textiles are identified as having a special importance for developing countries' growth performance. Peneder (2002) also finds that specialization in services represents a burden to future growth whereas exports of technology driven and high skill intensive industries have positive effects on aggregate growth.

In the meanwhile, although many literatures studied the contributions of export on China's surprisingly economic growth, few literatures study the consequences of such export composition adjustments in China shown in table one, in particularly to investigate the relationships between China's high-tech products exports and technology spillover. With a consideration of the effects of export composition on China's economic growth, this paper postulates that not only exports per se affect growth, but that the composition of exports is also crucial to study the economic development. Therefore, we attempt to empirically examine the growth effect of China's export composition by using China's panel data of 31 provinces during 1998-2005.

The key question we ask in this paper is whether the rapid development of China's high-tech goods export causes technology spillover towards other traditional export sectors and domestic one. To investigate the spillover effect of one sector towards others, Feder (1982) develops an analytical framework to explicitly describe the spillover effect, and hence to allow to test for productivity differentials and spillovers between the export and the non-export sector². Feder (1982) also adopts his sample data of 31 countries during 1964-1973, and finds that export promotes economic growth through causing spillover effects towards non-export sectors. Based on some important evidences from Feder's studies, this paper establishes a generalized multi-sectors spillover model through dividing the total export sector into three sub-sectors of primary goods export, manufactured goods export as well as high-tech export. In our multi-sectors spillover model, we do not only examine the growth and technology spillover effects from different export sectors, but also compare productivity differentials among different sectors.

Two different types of technology spillover are identified in this paper. The first is "between-spillover" effects, which measure technology spillover of various export sectors towards indigenous firms, while the second is "within-spillover" effects, which refer to technology

² In a much-cited contribution to the growth literature, Feder (1982) proposed a model of growth for less developing countries (LDCs) that recognized the importance of dualism – in his case, technology differences between sectors. Feder incorporated sectoral disequilibrium in the form of a productivity differential, and externality spillovers between two sectors, into a neoclassical growth model, using an export/non-export distinction. This approach underlies most subsequent investigations of dualistic growth, though an agriculture-manufacturing distinction has more commonly been adopted (see Dowrick, 1990; Dowrick and Gemmell, 1991).

spillover of high-tech export towards other traditional export sectors. Although Feder studied the between-spillover of exports (Feder 1982), the roles of within-spillover are less considered in economic literatures, which is very important for such developing country like China whose economic growth largely depends on its economic opening and export. In fact, different export sectors are highly possible to cause technology spillover effects towards each other, especially the development of high-tech product export in China may possibly promote technology upgrading and innovation activities in those traditional export sectors, which are acknowledged to be the main purposes of China's strategy of "Revitalizing the Trade through Science and Technology". Therefore, through introducing within-spillover effects among different export sectors, it makes it feasible to comprehensively evaluate the outcome of such export development strategy in China³.

With a consideration about the significant regional development disparity in China (Pedroni and Yao, 2006), this paper further attempts to test whether technology spillover effects of export significantly vary among different regions. Compared with the Central and West regions, it is well known that China's East Coastal Region has not only a larger volume of total exports, but also a much higher share of high-tech product export. In terms of high-tech products export in China, for example, in 2007 among the top ten provinces only Sichuan locates in the non-coastal regions. The share of high-tech products export in the national total in the top three regions, Guangdong, Jiangsu and Shanghai, has been as high as 37.7%, 25.2% and 16.6% respectively, and the sum of the three regions' share has amounted to 80 percent. Accordingly, to better understand the role of export composition in China's regional economic development, it is necessarily important to examine the growth and technology spillover effects among different regions in China. In summary, this paper investigates whether technology spillover effect of export is more significant in China's coastal regions than in its non-coastal ones.

3. The Set-up of Generalized Multi-sector Spillover Model

Based on a basic conceptual idea by Feder (1982), the whole economy could be divided into two sectors: domestic sectors and export sectors, and hence the total output Y is the sum of output

³ For example, Xu et al. (2005) extends Feder's two-sector spillover model by distinguish primary goods export from manufactured goods export, and the authors find that technology spillover mainly occurs in manufactured export sector. Bao (2007) further consider the determinants of export's technology spillover, like financial development, human capital and technology absorptive capacity. However, all these studies haven't considered the importance of high-tech products export, and therefore fail to investigate technology spillover among different export sectors either.

in both domestic sector (N) and export sector (X), which can be presented as $Y = N + X$. This paper extends the original Feder's two-sector spillover model into a multi-sector model, which specifies the export sector composed of three sectors, i.e., primary goods export sector (X_p), traditional manufactured goods export sector (X_m) as well as high-tech goods export sector (X_h). Therefore, we have $X = \sum X_j$. Their production functions are as follows respectively:

$$X_j = X(K_{X_j}, L_{X_j}), \quad j = p, m, h \quad (1)$$

$$N = N(K_N, L_N, X_p, X_m, X_h) \quad (2)$$

Equation (1) is the production function for the three export sectors, while the subscript p, m, h means primary export, manufactured export and high-tech export respectively⁴. The output level X depends on the capital stock (K_X) and labor input (L_X) in each export sector. For domestic sector, its output is not only the function of its own capital stock (K_N) and labor inputs (L_N), but also that of the three export sectors, where X_j captures technology spillover of the j export sectors. Suppose there is productivity differential between various export sectors and domestic sector:

$$\frac{X_{K_X}}{N_{K_N}} = \frac{X_{L_X}}{N_{L_N}} = 1 + \delta_j, \quad j = p, m, h \quad (3)$$

where lower-case subscript indicates partial derivatives of the function with respect to subscripted input, which just measures the marginal product of that input in certain sector. Furthermore, $X_{K_X} = \partial X / \partial K_X$, $N_{K_N} = \partial N / \partial K_N$ denotes marginal product of capital in export and domestic sectors respectively, and the same goes to the marginal product of labor in the export and domestic sectors X_{L_X} , N_{L_N} . It can be seen from equation (3) that the parameter δ_j captures the productivity differential between the j export sector and domestic sector. It is obvious that a positive δ_j means that productivity in the j export sector is higher than that in domestic sector. Hence, the total output is:

$$Y = N(K_N, L_N, X_p, X_m, X_h) + \sum X_j(K_{X_j}, L_{X_j}) \quad (4)$$

Differentiating the above equation (4) it yields:

$$dY = N_{K_N} .dK_N + N_{L_N} .dL_N + \sum N_{X_j} dX_j + \sum \delta_j (N_{K_N} dK_{X_j} + N_{L_N} dL_{X_j}) \quad (5)$$

Where $N_{X_j} = \partial N / \partial X_j$ refers to the marginal spillover effect of the j export sector towards

⁴ While manufactured goods include both high-tech products and traditional manufactured goods, or non-high-tech manufactured goods, it should be mentioned that here "manufactured goods export" only refers to traditional manufactured goods export, which excludes high-tech goods export.

domestic sector. Note $dK = dK_N + \sum K_{X_j}$, $dL = dL_N + \sum L_{X_j}$, it can be derived from equation (5):

$$\begin{aligned} dY &= N_{K_N} \cdot dK + N_{L_N} \cdot dL + \sum N_{X_j} dX_j + \sum \frac{\delta_j}{1 + \delta_j} (X_{K_{X_j}} dK_{X_j} + X_{L_{X_j}} dL_{X_j}) \\ &= N_{K_N} \cdot dK + N_{L_N} \cdot dL + \sum (N_{X_j} + \frac{\delta_j}{1 + \delta_j}) dX_j \end{aligned} \quad (6)$$

Suppose there is a linear relationship between the marginal product of labor and output per capita: $N_{L_N} = \mathcal{G} \cdot Y / L$. Hence, the following equation can be derived by dividing (6) by Y :

$$\frac{dY}{Y} = \gamma \cdot \frac{dK}{Y} + \mathcal{G} \cdot \frac{dL}{L} + \sum (N_{X_j} + \frac{\delta_j}{1 + \delta_j}) \cdot \frac{dX_j}{X_j} \cdot \frac{X_j}{Y} \quad (7)$$

While $\gamma = N_{K_N}$, which measures the marginal product of capital in domestic sector. The value of the two parameters γ , \mathcal{G} can be determined by regressing equation (7), however, the major problem lies in that it's hard for us to distinguish the spillover effect of export sector (N_{X_j}) with the productivity differential between export and domestic sector (δ_j). Therefore, to explicitly identify the technology spillover effects of various export sectors, we have to separate it from the productivity differential. To do this we follow Crespo and Worz (2005) to assume the following production function in domestic sectors:

$$N = (\prod X_j^{\varphi_j}) \cdot \tilde{N}(K_N, L_N) \quad (8)$$

Where the parameter φ_j measures output-elasticity of technology spillover from the j export sector. Combing with equation (7), it finally yields our basic estimation model:

$$\frac{dY}{Y} = \gamma \cdot \frac{dK}{Y} + \mathcal{G} \cdot \frac{dL}{L} + \sum [\varphi_j \frac{dX_j}{X_j} (1 - \frac{\sum X_j}{Y}) + \frac{\delta_j}{1 + \delta_j} \frac{dX_j}{X_j} \frac{X_j}{Y}] \quad (9)$$

4. Estimation Model and Data Source

In terms of our analysis, three econometric models can be established the following above:

$$\text{Model 1: } (dY/Y)_{it} = \alpha_1 \cdot (dK/Y)_{it} + \alpha_2 \cdot (dL/L)_{it} + \alpha_3 (\hat{X} \cdot X/Y)_{it}$$

$$\text{Model 2: } (dY/Y)_{it} = \beta_1 \cdot (dK/Y)_{it} + \beta_2 \cdot (dL/L)_{it} + \sum \beta_{3j} (\hat{X}_j \cdot X_j/Y)_{it}$$

$$\text{Model 3: } (dY/Y)_{it} = \lambda_1 (dK/Y)_{it} + \lambda_2 (dL/L)_{it} + \sum \lambda_{3j} (\hat{X}_j N/Y)_{it} + \sum \lambda_{4j} (\hat{X}_j X_j/Y)_{it}$$

The first model is used to estimate the direct effect of export development on economic growth, while the parameter α_3 measures the growth effect of export. The terms of \hat{X} denotes the growth rate of export. The second model further considers the role of export composition in

economic growth, while the parameter β_{3j} measures the growth effect of the j export sector. The third model makes a distinction between the two channels through which export may affect economic growth. The first is the technology spillover of export sector towards domestic sector, which can be captured by the parameter λ_{3j} . The second is the advantage of higher productivity in export sectors, which is measured by the productivity differential in equation (3). A simple calculation leads us to know that productivity differential between the j export sector and domestic sector is actually $\delta_j = \lambda_{4j} / (1 - \lambda_{4j})$.

The panel data involving 31 provinces in China during 1998-2005 are employed in our empirical models, while the subscripts i, t denotes certain province and year respectively. The output level (Y) is measured as GDP for each province, and we use the indicator of real GDP to delete inflation rate. The original data of GDP, investment and labor employments are all from various issues of China's Statistical Yearbook. We also collect our export data from various issues of Provincial Statistical Yearbook.

For our panel data estimation method, the usual Hausman test is employed to choose fixed effect (FE) or random effect models (RE). If the value of the Hausman test statistic is larger than the critical value, this means that the null hypothesis can be rejected and that fixed effects are to be preferred to random effects. The White cross-section method is also derived by treating the panel regression as a multivariate regression, and computing White-type robust standard errors for the system of equations. This estimator is robust to cross-equation (contemporaneous) correlation as well as different error variances in each cross-section (Wooldridge, 2002).

5. Estimation Results on Between-Spillover Effects

5.1 Estimation Results for all the 31 provinces

We first use all the 31 provinces' sample data to estimate the three econometric models respectively, and the estimation results are shown in table two.

[Insert table two]

Our estimation results demonstrate that on average one unit increase in the investment-output ratio (I/Y) will cause a 0.401 increase in China's economic growth rate, and one percent increase in labor growth rate will lead to a 0.573 increase in economic growth. The *wald* test shows that the constant return to scale assumption $\alpha_1 + \alpha_2 = 1$ is satisfied for China's production function. In the meanwhile, export is also another driving force of China's rapid economic growth,

and the marginal growth effect of export is roughly 0.192.

The second model further estimates the growth effects of export composition. Similarly, it's found that capital stock and labor inputs are also the major determinants of China's economic growth. However, it's also revealed that the roles of different export sectors significantly vary. Specifically, the co-efficient of primary and manufactured goods export is estimated negative, while that of primary export is statistically insignificant. By comparison, the estimated co-efficient of high-tech goods export is significantly positive. Our results demonstrate how the growth effect of export sectors differs in China. As one unit increase in traditional manufactured goods export X_m causes output to decrease 0.167, and one unit increase in high-tech goods export leads to a 0.347 increase in output, hence the combined marginal effect of manufactured goods export on output is 0.18. As during our sample period manufactured export has accounted for a large share in the total export, therefore we may conclude that the growth effect of export is roughly 0.18, which is consistent with our estimated co-efficient of the total export 0.192 in model one.

Model three estimates the two channels how export composition may affect economic growth, i.e., technology spillover effect and the productivity advantage effect. It's shown that for primary goods export, it neither has an obviously higher productivity than domestic sector, nor causes technology spillover towards the latter. While traditional manufactured goods export hasn't shown an advantage of higher productivity, it has technology spillover effect on domestic sector (0.026). By comparison, although high-tech goods export has an obvious advantage of higher productivity, it doesn't consequently cause significant technology spillover towards domestic sector⁵. Specifically, as the parameter λ_{4t} is estimated as 0.397, it's easy to know that the relative productivity of high-tech goods export sector is roughly 1.67 times that of domestic one according to equation (3). Furthermore, if we compare their productivities among the three export sectors, we can know that high-tech export sector also has a higher one than the other two sectors.

The sources of China's regional economic development can therefore be concluded based on our estimation results in table two. Generally the rapid economic growth in China is essentially driven by its factor accumulation, since both physical capital stock and labor employments are the two key variables in explaining economic growth rate. According to our estimation the contribution of physical capital and labor inputs is around 0.4 and 0.5 respectively, and this result is also consistent with others (Wang and Yao, 2003). For the role of export in China's economic

⁵ One problem in our estimation of model three is that high-tech goods export may be endogenous, i.e., rapid economic growth may also promote high-tech goods export. To deal with such endogeneity problem, we introduce the lagged-term of high-tech goods export as the instrumental variable of high-tech export. Our instrumental variable estimation result is very similar with that in table three: although high-tech goods export sector has a higher productivity than the domestic one, it doesn't cause significant technology spillover towards the latter.

growth, while it's found that generally the total export volume is another driving force of economic growth, the growth effects of different export sectors essentially differ with each other. The role of primary goods export is rather weak, and even negative technology spillover of primary export is estimated. While traditional manufactured goods export causes technology spillover towards domestic firms, there is no strong evidence that this sector uses more advanced technology and has higher productivity. Finally, while the tech-tech export sector has a higher productivity than domestic sector, such productivity advantage hasn't resulted in significant technology spillover effect yet.

5.2 Sub-sample Estimation Results

Both export volume and export compositions notably vary among different regions due to China's remarkable regional development disparity. Specifically, East regions lead far ahead in terms of both trade volume and export structure than the inland partners. It can be seen from table three that during our sample period the mean value of export for the eleven eastern provinces is 31.143 billion US\$, much higher than that of Central and West regions. Additionally, the shares of manufactured goods and high-tech goods export in East regions are also higher than those in other regions. Take high-tech goods export as an example. The mean value of Share of high-tech products export in the total export for the East provinces is as high as 19.59 percent during 1998-2005, and by comparison it's only 4.79 percent, 8.56 percent for the Central and West provinces. Therefore, we further divide our total sample into the following three regions: East, Central and West⁶, to examine whether the role of export in economic development significantly varies among different regions.

[Insert table three]

Our sub-sample estimation results are also shown in table two. In terms of the role of factor inputs, it's estimated that the co-efficient of investment-output ratio (I/Y) is all significantly positive for the three regions, which supports the key role of capital accumulation in China's regional economic growth. By comparison, the marginal growth effect of investment in East provinces (0.26) is smaller than the two inland regions (0.39 for the Central and 0.36 for the

⁶ As usual, the eastern coastal regions are 12 provinces, municipalities and autonomous regions, including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. The central regions include 9 provinces, municipalities and autonomous regions, Shanxi, Neimenggu, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hunan and Hubei. The west regions include 10 provinces, municipalities and autonomous regions, Sichuan, Chongqing, Guizhou, Yunnan, Shanxi, Gansu, Qinghai, Ningxia, Tibet and Xinjiang.

West). Such result may be possibly attributed to diminishing marginal product of capital. Since the physical capital stock is much higher in East regions than in the Central and West regions, the marginal growth effect of capital accumulation in East regions is accordingly expected to be smaller. In the meanwhile, the contribution of labor employments in East provinces is larger, and such result can also owes to its higher stock of capital in that more physical capital helps to improve the marginal product of labor in East regions due to the complementarities between capital and labor.

We are especially interested in whether the role of export differs among the three regions. First, in terms of relative productivity of various export sectors, it's found that the co-efficient of high-tech goods export in East regions is significantly positive (0.308) and a simple calculation shows that productivity of high-tech export sector in the East is roughly 1.45 times higher than domestic sector. While the co-efficient of high-tech export in the primary and traditional manufactured export is estimated statistically insignificant, it seems that their productivity is roughly equal with domestic sector since we can't reject the hypothesis $\delta = 0$. The estimation result in Central regions is very similar with that in East regions. A higher productivity is only found in the high-tech goods export sector, and our estimation shows that it's 1.5 times higher than domestic one. As for West regions, since the co-efficient of the three export sector is all estimated negative and also statistically insignificant, we can conclude that there is no strong evidence that export firms in West regions have a higher productivity as their domestic partners. Second, we also consider whether technology spillover of export is more significant in East regions. According to our estimation for East provinces traditional manufactured export sector has a significant technology spillover effect (0.016), while the spillover effect of the other two export sectors (X_p, X_h) is estimated statistically insignificant. The same goes to export sectors in West regions, which shows that technology spillover effect is only found in manufactured goods export sector. However, technology spillover effect doesn't occur for all the three export sectors in Central provinces. Specifically, while the co-efficient of manufactured export is insignificant, there is negative spillover for both primary and high-tech export sectors in Central region.

Therefore it can be concluded that our sub-sample estimation results of the three regions are very consistent with that of the national total sample. Although our econometric estimation supports the hypothesis that high-tech export sector has an advantage of superior productivity, such production advantage doesn't expectedly cause significant technology spillover towards

domestic firms. In the meanwhile, significant technology spillover is mainly found in the traditional manufactured export sector. Our estimation result is similar with Ghatak et al. (1997) and Herzer et al. (2006). In their empirical studies on Chile and Malaysia, the authors also find that manufactured export helps to enhance productivity of domestic firms. However, we further reveal that such technology spillover only occurs in traditional manufactured goods export instead of high-tech export in China's case.

6. Estimation Results on Within-Spillover Effects

6.1 Setup of the Econometric Model

Our estimation results in table two only consider the between-spillover effect, i.e. technology spillover of various export sectors towards domestic firms. However, it's highly likely that the development of high-tech product export also cause technology spillover towards the primary and traditional manufactured export, which we call "within-spillover". To capture such within-spillover effect among different export sectors, we further revise our econometric model as follows:

$$X_j = X(K_{X_j}, L_{X_j}, X_h), \quad j = p, m \quad (10)$$

The above equation (10) is the production function for the primary and manufactured export sector. Like domestic sector's production function, output in the two export sectors depends on not only their own factor inputs of physical capital and labor, but also the technology spillover of high-tech goods export, which is identified as X_h . Hence, differentiating equation (10) yields:

$$dX_j = X_{K_{X_j}} dK_{X_j} + X_{L_{X_j}} dL_{X_j} + X_{jh} dX_h \quad (11)$$

Where $X_{jh} = \partial X_j / \partial X_h$ measures the marginal product of high-tech export through technology spillover in the j export sector. Therefore, $X_{jh} dX_h$ captures the increase of the j export sector's output due to high-tech goods export growth. Differentiating the production function (4) for the whole economy, we have now:

$$dY = N_{K_N} dK_N + N_{L_N} dL_N + \sum N_{X_j} dX_j + \sum \delta_j (N_{K_N} dK_{X_j} + N_{L_N} dL_{X_j}) + \sum \frac{1}{1 + \delta_j} X_{jh} dX_h$$

Combining it with equation (4), we have:

$$dY = N_{K_N} dK + N_{L_N} dL + \sum (N_{X_j} + \frac{\delta_j}{1 + \delta_j}) dX_j + \sum \frac{1}{1 + \delta_j} X_{jh} dX_h \quad (12)$$

The above equation explicitly demonstrates that economic growth is determined by the following four issues. The first is the role of factor accumulation, which is measured by $N_{K_N} dK + N_{L_N} dL$. The second is the advantage of higher productivity in export sectors

against domestic firms, which is identified $\sum \delta_j / (1 + \delta_j) dX_j$. The third is technology spillover effect of various export sectors towards domestic firms $\sum N_{X_j} dX_j$. The fourth is technology spillover effect of high-tech goods export towards the other two traditional export sectors, which is $\sum X_{jh} dX_h$. Like domestic sector's production function (8), we further assume that production function (10) is as follows:

$$X_j = X_h^{\eta_j} \cdot \tilde{X}_j(K_{X_j}, L_{X_j}), \quad j = p, m \quad (13)$$

Substituting equation (13) into (12), and dividing it by the total output Y , we finally have our estimation model as follows:

$$\frac{dY}{Y} = \gamma \cdot \frac{dK}{Y} + \vartheta \cdot \frac{dL}{L} + \sum [\varphi_j \cdot \hat{X}_j \frac{N}{Y} + \frac{\delta_j}{1 + \delta_j} \hat{X}_j \frac{X_j}{Y}] + \sum \frac{\eta_j}{1 + \delta_j} \hat{X}_h \frac{X_j}{Y} \quad (14)$$

6.2 Estimation Results

The estimation results on the within-spillover effect of high-tech export are shown in table four. Similar with table two, it's found that both physical capital accumulation and labor inputs are the major driving forces of China's economic growth.

[Insert table four]

As for productivity differential between export sectors and domestic firms, our estimation results show that except the West region, a higher productivity in high-tech export sector is found for both East and Central region, which is 1.79 times and 1.77 times higher than their domestic partners respectively. Furthermore, the co-efficient of both primary goods and traditional manufactured goods export sector is statistically insignificant, which demonstrates that there is no evidence that those export sectors' production is more efficient than the domestic one.

Let's further consider technology spillover effects of export sectors. Firstly, generally technology spillover effect on domestic sector is only discovered in the traditional manufactured export sector. Specifically, except the Central region, the estimated co-efficient of X_m is 0.026, 0.004 and 0.024 for our total sample, East region and West region respectively. In the meanwhile, a negative spillover effect of primary goods export is estimated among our total sample and the Central region sample, although its effect is very weak. In table four we consider two kinds of spillover effects for the high-tech goods export, say, the between-spillover and within-spillover effects. As for its technology spillover towards domestic sector, although the co-efficient of high-tech export is estimated positive for both total sample and the East region, it's statistically insignificant yet. Additionally, a weak negative technology spillover effect of high-tech export is revealed for our Central region sample (-0.0054). Hence, Consistent with table two, there is no strong evidence that support there is positive between-spillover effect of high-tech goods export

for all our four samples. Has high-tech goods export sector promoted the growth of other traditional goods export? Let's first consider technology spillover of high-tech goods export towards primary goods export. Although such technology spillover effect is estimated positive, the estimated co-efficient failed to show statistically significant. We are very interested in whether high-tech goods export promotes other manufactured goods export's growth. However, our estimation results failed to support such within-spillover effect again.

Therefore, although China's high-tech goods export has experienced a rapid growth period, largely owing to the implementation of the strategy "Revitalizing the Trade through Science and Technology", high-tech goods export doesn't consequently cause significant technology spillover towards both domestic and other export sectors. Such estimation result reflects two features of China's high-tech goods export, in terms of both export firms' ownership and export pattern in high-tech goods trade. The first is the dependence of China's high-tech export on the foreign affiliates. For example, in 2006 high-tech goods export by foreign-invested firms amounts to 229.438 billion US\$, which accounts of 88.1 percent of its total high-tech goods export 281.45 billion US\$. By comparison, China's domestic firms only export high-tech goods of 33.59 billion US\$, which is only 13 percent of the foreign-invested firms'⁷. The second is the dependence of China's high-tech export on processing trade. Also take 2006 as an example, the processing high-tech export's value is 245.82 billion US\$, and its share in China's total high-tech export is as high as 87.3 percent. As a matter of fact, processing exports of high-tech products accounted for nearly 90 percent of China's total high-tech export every year since 1998 (see table five). By comparison, the share of general export has reduced to 12.7 percent in 2006 from 23.4 percent in 1994. What should be mentioned here is that the phenomenon of "two-dependence" occurs not only in China's high-tech goods export, but also for China's total export in the past decades. However, compared with other types of export, the dependence on foreign-funded firms and processing trade becomes more serious in terms of China's high-tech goods export. For example, the share of processing trade in China's total export has stably maintained around 55 percent since 1998 according to the statistical information provided by China's Ministry of Commerce, and by comparison the share of processing trade in China's high-tech export has been as high as nearly 90 percent during the same period (see table five). The same goes to the role of foreign firms. While exports by foreign invested firms accounted for more than half of China's exports since 1998, it becomes more than 80 percent of China's high-tech export every year since that time (see table five). Therefore, the contribution of foreign-funded firms and processing trade becomes much

⁷ Such phenomenon is partly due to the fact that foreign investors are encouraged to invest in high-tech and environment friendly projects instead of resources-intensive sectors, as shown in the newest edition of the Catalogue of Industries for Guiding Foreign Investment, jointly issued by the National Development and Reform Commission (NDRC) and the Ministry of Commerce in December, 2007.

more significant in terms of China's high-tech goods export compared with that in its total export⁸.

The two-dependence type of China's high-tech goods export partly explain our estimation result that why technology spillover from high-tech export is insignificant. For Foreign-invested firms' processing export, especially for processing export with imported materials, it's the foreign investors who makes the production decision and manipulate the firm's operation. As for the processing export by China's indigenous firms, they usually export their goods with processing trade with supplied materials, and the production and export decision are made by their foreign partners⁹. As most high-tech goods exported are assembled not by Chinese owned firms but by foreign firms that are using China as an export platform, high-tech goods export sector consequently has less industrial linkage with China's domestic market and indigenous firms. Taking such characteristics of China's high-tech export into account, the development pattern of high-tech export is just like an "isolated-island" one, which isolated from China's whole economy, and such pattern significantly constrains technology learning opportunity for domestic partners. The isolated-island development pattern is further supported by the fact that China's high-tech goods export is also highly concentrated in terms of both export sources and commodities. For example, in 2005 the three coastal regions, Jiangsu, Shanghai and Zhejiang, their high-tech goods export sums up to 94.81 billion US\$, which amounts to 43.4 percent of the total high-tech export. If we look at the commodity catalogue of China's high-tech export, the three sectors of computer, communication and electronics have accounted for 48.0 percent, 33.1 percent and 11.2 percent, and their sum has been as high as 92.3 percent. Therefore, the isolated-island pattern of China's high-tech export can be concluded as "it's assembled by foreign firms through processing trade in a few regions for a few industries".

[Insert table five]

7. Conclusion

Based on the above analyses, this paper concludes that a generalized multi-sector spillover

⁸ Some authors have considered the role of FDI and processing trade in the technology sophistication of China's total trade. For example, Amiti and Freund (2008) show that once excluding processing export from China's total export, there is no evidence of significant skill upgrade. Xu and Lu (2009) use China's industry-level data to 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. The key role of processing trade and foreign invested firms in China's export sophistication development is consistent with our estimation result in this paper.

⁹ It has been long debated whether foreign-invested firms have technology spillovers towards China's indigenous firms, and there is a large number of empirical studies on this issue. However, their estimation results are rather mixed, partly explained by some econometric problems such as omitted variables, model specification as well as measurement errors (Hale and Long, 2006). Additionally, technology spillover effect of FDI also depends on the source of foreign investment. For example, Ma (2006) uses China's panel data of provinces and finds that there is significant spillover effect of foreign firms from OECD countries, but it's not true for foreign investors from Hong Kong, Tai Wan and Macao.

model can be adopted to investigate whether the rapid development of high-tech products export in China has caused significant technology spillover towards both domestic sector and other traditional export sectors. This hypothesis is examined empirically through China's panel data of 31 provinces during 1998-2005 in this paper.

This paper certifies that China's implementation of strategy of "Revitalizing the Trade through Science and Technology" has remarkably promoted China's high-tech products export. It's estimated that high-tech products export sector involve a higher productivity than both indigenous firms and other export sectors. Furthermore, productivity in high-tech export sector is around 1.5 times higher than domestic sector. However, such productivity advantage in high-tech export sector hasn't effectively caused significant technology spillover towards other sectors, which constrains the role of high-tech export in China's economic growth. In other words, the role of high-tech export is identified only by its own superior productivity due to the use of more advanced technology, but not by its significant technology spillover as we expect. Additionally, we have also comprehensively evaluated the driving forces of China's regional economic growth. Specifically, as most studies show, factor inputs including both physical capital and labor employment are the two key driven forces of China's rapid economic growth. The role of export is captured by two aspects: one is enhancement of productivity in high-tech goods export sector, the other is technology spillover of traditional manufactured goods export towards domestic firms.

Our estimation results also convey certain policy implications. Firstly, compared with the enlargement of export volume, adjustment of export composition has profound effect on China's economic growth, especially the rapid development of high-tech goods export since it remarkably enhances the production efficiency. As the share of high-tech export is as high as 40 percent among developed economies, China's high-tech export still has a large development potential, especially for its inland regions. However, while foreign invested firms and processing trade play key roles in China's high-tech export in the past years, such isolated-island development pattern of China's high-tech export is expected to be changed through promoting the role of China's indigenous firms in high-tech goods export, especially through stimulating the R&D activities and technology innovation among China's domestic firms to build up its own technological capacity. Secondly, while China's high-tech export develops rapidly, the linkage between high-tech export and other sectors is expected to be strengthened. While both between-spillover and within-spillover are not found in our estimation results, China's high-tech export is expected to cause more technology spillover towards other sectors, and hence to help upgrade China's economic structure and promote its long-run economic growth.

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Table 1 Change of China's Export Composition (Unit: hundred million US\$)

	1998	2000	2002	2005	2007
Total export	1795.38	2492.0	3251.93	7619.5	12177.8
Primary export	197.61	254.6	260.41	490.4	615.1
Share of primary export (%)	11.01	10.22	8.01	6.44	5.05
Manufactured export	1597.78	2237.4	2991.52	7129.6	11562.7
Share of manufactured export (%)	88.99	89.78	91.99	93.57	94.95
High-tech export ¹⁰	246.36	408.18	724.97	2204.59	3478.3
Share of high-tech export (%)	13.72	16.38	22.30	28.93	28.56

Data Source: various issues of China's Statistical Yearbook 1999-2008.

¹⁰ According to China's statistical classification of its export, those export products using advanced technology in their production are classified as two parts: high-tech products, and new-tech products. We use the term "high-tech products" for simplicity in this paper, since a great portion of China's high and new-tech products export is high-tech export. For example, in 2005 high-tech export accounts for 86.6 percent among the total high and new-tech export in China. Some authors also use other term to name high and new technology goods export. For example, Ferrantino et al. (2007) call them "ATP export (advanced technology products export)".

Table 2 Estimation Result on Between-Spillover Effect

	Total Sample			East	Central	West
	Model 1	Model 2	Model 3	Model 3	Model 3	Model 3
C	-0.0656 ^{***} (-4.171)	-0.0594 ^{***} (-3.113)	-0.0582 ^{***} (-4.044)	-0.0062 (-0.151)	-0.0427 (-0.956)	-0.0701 [*] (-1.646)
I/Y	0.4012 ^{***} (11.42)	0.3919 ^{***} (9.053)	0.3864 ^{***} (11.31)	0.2603 ^{**} (2.522)	0.3907 ^{***} (3.177)	0.3668 ^{***} (3.772)
dL/L	0.5725 ^{***} (3.736)	0.4893 ^{***} (3.024)	0.4783 ^{***} (3.004)	0.5972 ^{**} (2.056)	0.2592 (0.958)	0.2792 (0.362)
$\hat{X}.X/Y$	0.1920 ^{***} (4.034)					
$\hat{X}_p.X_p/Y$		-0.1065 (-0.843)	0.2748 (1.062)	-0.1595 (0.278)	1.2060 (1.032)	-0.6717 (-0.7638)
$\hat{X}_m.X_m/Y$		-0.1673 ^{***} (2.651)	-0.0004 (-0.011)	0.1062 (1.017)	0.5461 (0.867)	-0.0437 (-0.363)
$\hat{X}_h.X_h/Y$		0.3467 ^{***} (4.767)	0.3976 ^{***} (7.702)	0.3083 ^{***} (2.669)	0.3347 ^{**} (16.042)	-0.786 (-1.201)
$\hat{X}_p.N/Y$			-0.0089 [*] (-1.876)	0.0115 (0.605)	-0.0299 ^{**} (-2.548)	0.0077 (0.448)
$\hat{X}_m.N/Y$			0.0264 ^{***} (3.570)	0.0163 (0.735)	0.0338 (1.465)	0.0251 [*] (1.793)
$\hat{X}_h.N/Y$			0.0005 (0.298)	0.0048 (0.521)	-0.0065 ^{***} (-2.753)	0.0025 (1.143)
$adj - R^2$	0.542	0.558	0.604	0.581	0.815	0.644
χ^2 -statistic	369.11	389.77	338.24	445.29	341.79	315.06
Hausman-test	32.75	28.31	35.97	33.65	35.86	30.01
Sample	248	248	248	88	80	80

Note: t -statistic values are in the parentheses, and ***, **, * means significant at 1%, 5% and 10% level respectively; χ^2 -statistic is used to testify whether the specific cross-section and period effects are both significant at the same time, and Hausman-test is used to specify whether we choose fixed effect model or random effect model.

Table 3 Export Development in the Three Regions in China

	East Regions	Central Regions	West Regions
Total Export (Hundred Million US\$)	311.43	20.66	11.14
The Share of Manufactured Export (%)	86.03	77.15	82.59
The Share of High-tech Export (%)	19.59	4.79	8.56

Note: all the values in the table are the mean value for various indicators, and the sample period is also 1998-2005.

Data Source: various issues of Provincial Statistical Yearbook in China.

Table 4 Estimation Results on Within-spillover Effect

	Total Sample	East	Central	West
C	-0.0566*** (-3.8671)	0.0035 (0.1036)	-0.0481 (-0.9771)	-0.0657 (-1.3944)
I/Y	0.3834*** (10.998)	0.2414*** (2.6981)	0.4061*** (3.0232)	0.3605*** (3.4582)
dL/L	0.4784*** (2.9597)	0.5785** (2.0001)	0.2343* (1.8493)	0.2552 (0.3302)
$\hat{X}_p \cdot X_p / Y$	0.2714 (1.0479)	-0.1533 (-0.5501)	1.2260 (1.1554)	-0.9122 (-0.6293)
$\hat{X}_m \cdot X_m / Y$	0.0009 (0.0224)	0.1692 (1.4421)	0.2965 (0.4141)	-0.0312 (-0.2644)
$\hat{X}_h \cdot X_h / Y$	0.3978*** (5.8069)	0.4422*** (2.7154)	0.4344*** (8.3234)	-0.2787 (-0.3359)
$\hat{X}_p \cdot N / Y$	-0.0091* (-1.8515)	0.0111 (0.5821)	-0.0276** (-2.0576)	0.0141 (0.5504)
$\hat{X}_m \cdot N / Y$	0.0267** (3.5567)	0.0045** (2.1794)	0.0408 (1.5456)	0.0236* (1.8613)
$\hat{X}_h \cdot N / Y$	0.0036 (0.6725)	0.0156 (0.4578)	-0.0054 (-5.5697)***	-0.0092 (-0.5471)
$\hat{X}_h \cdot X_p / Y$	-0.1494 (-1.1364)	0.0044 (0.0054)	0.0758 (0.6967)	0.1259 (0.1254)
$\hat{X}_h \cdot X_m / Y$	0.0023 (0.0657)	-0.1182 (-0.9878)	-0.0939 (-0.6531)	0.0880 (0.4128)
$adj - R^2$	0.6052	0.5797	0.7787	0.6963
χ^2 -statistic	301.76	363.27	366.29	367.18
Hausman-test	29.639	44.612	37.448	33.82
Sample	248	88	80	80

Note: t -statistic values are in the parentheses, and ***, **, * means significant at 1%, 5% and 10% level respectively; χ^2 -statistic is used to testify whether the specific cross-section and period effects are both significant at the same time, and Hausman-test is used to specify whether we choose fixed effect model or random effect model.

Table 5 China's High Technology Export: Firm Ownership and Trade Pattern

(Unit: hundred million US\$)

	2002	2003	2004	2005	2006
Total high-tech export	678.7	1193	1655.4	2182.5	2814.5
Foreign firms' high -tech export	557.9	990.2	1445.2	1919.5	2294.38
share of foreign firms' high -tech export (%)	82.2	83	87.3	87.95	88.1
Processing high -tech export	608.1	1073.7	1479	1948.9	2458.2
share of processing high -tech export (%)	89.6	90	89.4	89.3	87.3

Data Source: the author's calculation based on various issues of China's Science and Technology Statistical Annual Report, published by the Ministry of Science and Technology. As this report only contains the statistical information on China's high technology goods export, its value is somewhat different from the values in table one. However, if we compare the statistical information in table one and five, it can be known that most high and new technology export are high technology export.