An Analysis of Causal Links between Export and Productivity in China: A Heterogeneous Dynamic Panel Approach*1*2

Atsuyuki Kato†

This study examines the causal relationship between export and productivity (labour productivity and total factor productivity) in a sample of 28 Chinese provinces covering the period 1978–2002. Using the mean group estimators for a heterogeneous panel, we find bi-directional Granger causality between productivity and per capita exports. In addition, exports have a lasting impact on productivity while productivity carries no information about the long run level of exports. Thus, exports cause the level of productivity. However, the long run impact is not homogeneous between different regions. In general it is higher in the coastal provinces and lower in the inland provinces. Our results coincide with the implication of theoretical models that differences among trading partners have different effects on productivity growth through learning by doing.

1. Introduction

This paper aims to provide an answer to the following question. Does trade have a causal link to productivity in China in the long run? This question has drawn a lot of interest from economists because China has achieved a remarkable performance in economic growth since adopting its open-door policy in 1978. Many papers have shown that trade played an important role in stimulating growth during the reform period. However, productivity and trade performance vary considerably across the provinces. As those papers discussed, trade and in particular exports were highly concentrated in the coastal provinces. In addition, the earlier opened southeast coastal provinces achieved productivity growth rates of around 10 percent[1] while northeast and west provinces experienced substantially lower growth rates than the coastal leaders. This suggests that empirical analysis based on provincial data is important.

The relationship between trade and productivity growth is one of the fundamental subjects in the development literature. Since the 1960s, the successful performance of newly industrialised Asian economies (NIEs: Hong Kong, Singapore, South Korea, and Taiwan), and the stagnation of Latin American countries formed a theoretical consensus on export led growth in neoclassical economics.

† Graduate School of Asia-Pacific Studies Waseda University, E-mail: akato@aoni.waseda.jp

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*2 I am also grateful to Niklas Ahlgren (the Swedish School of Economics and Business Administration) for allocating his GAUSS code to conduct his bootstrap method of small sample correction for LR tests.

[1] 1. Zhejiang: 10.3% 2. Guangdong: 9.82%, 3. Fujian: 9.76%.

In the 1990s, endogenous growth models gave further development of the theoretical debates on this issue, and revealed that knowledge spillovers from advanced countries and learning-by-doing can contribute to growth in the long run. Many empirical studies have also examined those theoretical implications employing newly developed panel or time-series approaches, and find positive relations between them.

However, there still exist lots of controversies about this issue. Theoretically, implications from the models which formalise the relationship between trade and growth are not always identical. Some models say that trade is advantageous for advanced countries while others indicate that trade gives a positive contribution to the catching up of followers. In the empirical literature, although lots of papers find causality from trade to growth, many of them also find counter-directional causality as well, and interpretations of those results are complicated.

In this study, we examine the relationship between trade and productivity using Chinese provincial data for the 1978–2002 period and aim to contribute to the existing literature in the following ways. First, we specify a vector error correction model (VECM) for the log of the level of productivity and per capita exports. This model specification encompasses the model including only the growth rate of productivity as a sub-model, and corresponds to the neoclassical growth model as well as the endogenous growth model because the neoclassical growth model suggests a long-run relation between the levels of productivity and trade. Using this model specification, we test for Granger causality between them. In addition, we also test the neutrality hypothesis which makes the two approaches related; the cross-province growth studies using the period average and the time-series and panel approaches based on annual observations. To obtain robust results, we examine both labour productivity and total factor productivity (TFP).

Secondly, we adopt the heterogeneous panel method to allow the varying long run impacts of trade on growth across provinces. As recently developed models propose, the long run effects of trade on productivity are possibly different because of different trade partners and components. The mean group estimation by Pesaran and Smith (1995) gives us a consistent estimate of heterogeneous panel. In addition, we will also discuss if we find systematic patterns in the long run impacts of trade for individual provinces. A simple graphical analysis reveals the regional gaps between the long run impacts.

Thirdly, we will discuss the relation between the impacts of trade on productivity and some indicators, also relying on a simple graphical method. This sheds further light on the trade-growth relation. From the trade and growth literature, we examine the following indicators. Trade partners and components play important roles to form the effects in recently developed models. These two indicators are obtained as follows. The former is calculated as the product of the gaps of per capita GDP with their advanced trade partners and those partners' trade share. The gaps of per capita GDP are used as proxies for technological gaps. Thus, the larger technological gaps or share of technologically endowed partners are, the higher the scores of this indicator as well. On the other hand, the latter indicator is the share of manufacturing products in trade. The levels of human capital are assumed to form the higher long run growth. In the growth literature, educational attainment is largely used as a proxy for it. In addition, privatisation should be tested because China is a transition economy.

The rest of this study is organised as follows. In Section 2 we briefly review the existing literature of trade-growth relations and empirical studies on China. Section 3 describes the model and the methodology which we use. In Section 4, data issues are discussed. The empirical results are presented in Section 5. The concluding remarks follow in Section 6.

2. Brief Literature Review

In this section, we briefly review the existing literature of trade-growth relations and empirical studies on China. It makes clear what the remaining problems are. In theoretical debates, different roles are given to trade between exogenous and endogenous growth models. Although some papers (e.g., Krueger, 1984) indicate that free trade facilitates growth, the long run growth effects of trade are largely discussed in the works of endogenous growth models such as Rivera-Batiz and Romer (1991a, 1991b), Grossman and Helpman (1990, 1991a), Stokey (1991), and Young (1991).[2] In these papers, the former two discuss roles of innovations and international knowledge spillover as engines of growth while the latter focus on learning-by-doing over a length of time to explain production variation and trade pattern in the real world.

In the North–South framework, the model of Grossman and Helpman (1991b) concludes that the well developed North has permanently higher growth than the less developed South. Thus, the gap between them is persistent. Their model seems to appropriately explain differences of growth across developed countries while it is not consistent with the performance of Asian NIEs and China. In practice, it is not reasonable to consider innovation as the main engine of their rapid growth because they have a poorer accumulation of experience and knowledge.

On the other hand, Stokey and Young, respectively, form the models involving the introduction of new and technically sophisticated goods and the discarding of the old and less sophisticated goods in the learning-by-doing process. This seems to be more reasonable than innovation based growth in developing countries. However, the conclusions from their models are not consistent with the experience of rapidly growing developing countries, either. Under free trade, Young's model obtains the result that developed countries enjoy higher technical progress at the expense of the less developed countries. In Stokey's model, trade has disadvantageous effects on less developed countries. Even in their and some others' learning-by-doing models, less developed and developed countries tend to specialise in different goods in terms of utilised technologies. Less developed countries incline toward specialising in low-technology goods while developed countries are associated with high-technology goods. Thus, dynamic learning-by-doing reinforces the initial patterns of comparative advantage and forms the persistent gaps.

[2] Ben-David and Loewy (2003) modifies the neoclassical growth model to make the growth process endogenous and allow for the presence of both level and growth effects to arise from trade liberalisation.

Although their earlier models do not successfully explain the experience of developing countries including rapidly growing Asian NIEs, their rapid growth itself still implies that the learning-by-doing process through a large volume of trade possibly gives reasonable explanations in different growth paths of countries with similar endowments.[3] Chuang (1998) discusses this issue and proposes a growth model of trade-induced learning-by-doing. In his model, trade-induced learning facilitates growth of less developed countries under some suitable conditions, and forms the evolution of trade patterns through real growth effects of trade. His model gives us the following implications. In the learning based growth process, imports are just as important as exports. Differences in the effects of learning arise partly from the nature of the learning characteristics of traded goods. Secondly, openness of trade is a necessary but not a sufficient condition for rapid growth. For rapid growth through learning-by-doing, trade partners have significant meanings because the level of technology which a country can learn is dependent on that of her trade partners.

Empirically, the relationships between trade and growth are examined using some different approaches. Among them, growth regressions and causality tests are conducted in many studies. For the former studies, cross section or panel data approaches are applied to the log transformed growth model. Many papers detect that the coefficients on trade are significantly positive. In many cases, homogeneous coefficients on regressors are implicitly assumed although heterogeneous dynamic panel approaches are also applied. On the other hand, Granger causality tests are largely applied to time series data to directly examine causal relationships between variables. This approach is, in many cases, associated with the export-led growth (ELG) hypothesis and uses exports as a regressor instead of trade.

For China, Makino (1998) finds that trade is significantly positive and robust in Barro style growth regressions over the economic reform period. Using panel data, Yao (2001) also estimates a positive coefficient on trade in a neoclassical growth model. In their studies, homogeneity of coefficients across provinces is implicitly assumed. On the other hand, Yao (2001) applies the pooled mean group estimator of Pesaran and Smith (1999) to allow short-run heterogeneity and impose long run homogeneity. Jin (2004) undertakes a time series analysis to estimate the long run relation between trade and growth province by province, and finds that the relationships are heterogeneous between coastal and inland regions.

Granger causality tests are also applied to Chinese data. But it was conducted at the country level, not the province level. For example, Shan and Sun (1998) test Granger's non-causality between industrial output and some causal variables including export and import using the Toda-Yamamoto procedure (Toda and Yamamoto, 1995). They find bi-directional causality between exports and industrial output, and rejected the ELG hypothesis which is defined as unidirectional causality from exports to output. However, their results do not say that export plays no important role in the Chinese economy. In addition, causality tests at the provincial level also seem to be required because regional heterogene-

[3] Lucas (1993).

ity in China is significant.

3. Model and Estimation Methodologies

In this section, we specify unit-root and cointegration tests for the heterogeneous panel data and the model used to test causality in a heterogeneous panel framework. Since we examine annual series of observations, tests of time series properties are inevitable. In order to allow all parameters to be heterogeneous across provinces under the assumption of common structures, we perform the tests of time series properties on a province-by-province basis at first, and then the test results are combined to single panel test statistics following Hansen and Rand (2006).

The presence of unit-roots and cointegration in the provincial data are tested for using the likelihood ratio test (Johansen, 1988, 1991). As to his LR test, one problem is that the small sample distribution is not well approximated by the limiting distribution, as many studies have shown, and some different forms of correction methods are considered. Ahn and Reinsel (1990) and Reimers (1992) propose correction using degree of freedom. Johansen (2002) also suggests a correction method based on the Bartlett correction. Bootstrapping is also considered in this issue. Until now, some different bootstrap approaches are proposed. Among them, Davidson and MacKinnon (2000, 2006) suggest a fast double bootstrap based on Beran's double bootstrap (Beran, 1988). Ahlgren and Antell (2006) study the behaviour of different bootstrap approaches and their simulation shows that the fast double bootstrap produces an improvement on the ordinary single bootstrap in many cases. Here we also apply this approach to obtain the p-value of the LR test.

There are some different approaches to construct the test statistics of heterogeneous panel using the test statistics of individuals. In this study, we use the logit method proposed by George and Mudholkar (1983). In this test, the hypothesis of the independent province specific errors is maintained. The test is described as follows.

$$\text{logit } p = \sqrt{N}\,\frac{\frac{1}{N}\sum_{i=1}^{N}\log\left(\frac{p_i}{1-p_i}\right)}{\sqrt{\pi^2(5N+2)/\{3(5N+4)\}}}\ \underset{H_0}{\overset{d}{\Longrightarrow}}\ t_{5N+4} \qquad (1)$$

Using this method, we conduct unit root tests and cointegration tests first.

For testing the causality, we also follow Hansen and Rand, and apply bivariate vector autoregressive (VAR) models to our data, the log of labour productivity or TFP level and the log of per capita export. To simplify the notation, let $y_{it}=[\log(LP), \log(PcEXP)]'$, or $y_{it}=[\log(TFP), \log(PcEXP)]'$, where LP and $PcEXP$ respectively denote labour productivity and per capita export. The subscripts i and t denote provinces ($i=1, \ldots, N$) and time ($t=1, \ldots, T$). One issue to which we should pay attention in the VAR model specification is how many lags to include. In this study, we choose a third-order VAR model based on the results of the Schwartz information criterion (SIC) where the maximum lag considered is 4.[4] The VAR model which includes a province specific intercept (μ_i) and time trend (δ_i) is described as follows

$$y_{it} = A_{1i} y_{it-1} + A_{2i} y_{it-2} + A_{3i} y_{it-3} + \mu_i + \delta_i t + \lambda_t + \varepsilon_{it} \tag{2}$$

where A_{ji} are (2×2) matrices of parameters that are possibly heterogeneous across provinces. λ_t is a time specific component with zero mean. It is assumed to be identical across provinces. ε_{it} is an error term assumed to follow $iid(0, \Omega)$. μ_i, δ_i, λ_t and ε_{it} are (2×1) matrices. Our model includes the log of labour productivity or TFP level. If their growth rates have non-zero means, then their log will have trends. That is why we include province specific trends.

In the previous literature on causality issues, Granger causality is widely tested. In our model, using the notation of $a_{12(ji)}$ as (1, 2) elements in the A_{ji} matrices, Granger non-causality from export to labour productivity or TFP is defined as follows.

$$\begin{aligned} &H_0 \ (PcEXP \text{ doesn't Granger cause } LP): \quad a_{12(ji)} = 0 \\ &H_0 \ (PcEXP \text{ doesn't Granger cause } TFP): \quad a_{12(ji)} = 0 \end{aligned} \tag{3}$$

If the hypothesis is rejected, we conclude that exports Granger cause labour productivity or TFP. The hypothesis of the reverse causality (LP or $TFP \rightarrow PcEXP$) is also represented below.

$$\begin{aligned} &H_0 \ (LP \text{ doesn't Granger cause } PcEXP): \quad a_{21(ji)} = 0 \\ &H_0 \ (TFP \text{ doesn't Granger cause } PcEXP): \quad a_{21(ji)} = 0 \end{aligned} \tag{4}$$

where $a_{21(ji)}$ is the (2, 1)-elements in the A_{ji} matrices. The tests are carried out for $j=1, 2, 3$ for each i.

If two variables are integrated of order one ($I(1)$) and cointegrated then there must exist either unidirectional or bidirectional Granger causality, at least in their first differences, which are integrated of order zero ($I(0)$), according to Engle and Granger (1987).[5] Thus, equation (2) is transformed into the following vector error correction model (VECM) representation.

$$\Delta y_{it} = \Gamma_{1i} \Delta y_{it-1} + \Gamma_{2i} \Delta y_{it-2} + \Pi_i y_{it-1} + \mu_i + \delta_i t + \lambda_t + \varepsilon_{it} \tag{5}$$

where $\Pi_i = -(I - A_{1i} - A_{2i} - A_{3i})$, $\Gamma_{1i} = -(A_{2i} + A_{3i})$, and $\Gamma_{2i} = -A_{2i}$. In addition, $\Pi_i = \alpha_i \beta_i'$ has a reduced rank r that is the number of cointegrated vectors. Here, α_i represents the speed of adjustment to disequilibrium and β_i is a cointegrating vector (Johansen, 1991). In our model, $r=1$, and both α_i and β_i are (2×1) matrices. In equation 5, the dependent variables are the growth of productivity (labour productivity and TFP are alternatives) and per capita export.

Using the error-correction form, we do not need to change the hypothesis of Granger non-causality because equation (5) is a linear transformation of equation (2). In VECM, the hypothesis is described as follows.

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[4] Hansen and Rand (2006) also chose a third-order VAR model.

[5] Hondroyiannis and Papapetrou (1994).

$$H_0 \text{ (}PcEXP\text{ doesn't Granger cause }LP\text{ or }TFP\text{):} \quad \gamma_{12(ji)}=0 \text{ and } \pi_{12i}=0,\ j=1, 2$$
$$H_0 \text{ (}LP\text{ or }TFP\text{ doesn't Granger cause }PcEXP\text{):} \quad \gamma_{21(ji)}=0 \text{ and } \pi_{21i}=0,\ j=1, 2 \tag{6}$$

where $\gamma_{12(ji)}$ and π_{12i} are respectively (1, 2) elements of Γ_{ji} and Π_i matrices, and $\gamma_{21(ji)}$ and π_{21i} are (2, 1) elements. In some preceding research, the above Granger non-causality hypothesis is divided into two sub-hypotheses, short run causality and long run causality. In those studies, $\gamma_{12(ji)}=0$ and $\gamma_{21(ji)}=0$ mean short run Granger non-causality while $\pi_{12i}=0$ and $\pi_{21i}=0$ show long run Granger non-causality. In this study, following Hansen and Rand, we use the classical notion of Granger causality whose null hypothesis is described in equation (3).

However, Granger causality is not causality in a deep sense of the word. It just indicates whether one time series is useful in linearly forecasting another. It doesn't say how large the causal effects are, either. Therefore, we also discuss the neutrality hypothesis adding to Granger causality. As we discussed above, if neutrality hypothesis is accepted, a permanent increase or decrease in export (productivity) has no long-run effect on the level of productivity (export). Thus, there is no causal relationship using Sim's (1972) technique. In equation (5), the neutrality hypothesis is defined as off-diagonal zeros in the Π_i matrix, that is, $\pi_{12i}=0$ and $\pi_{21i}=0$.

One of the advantages using the neutrality hypothesis is that it can be used to make a connection between cross-country studies of growth using averages data for the examined period and the time-series or panel data approaches using annual observations. In the VECM framework, this issue can be discussed using the moving average impact matrix which is obtained from the Johansen-Granger representation theorem. According to this representation theorem, we obtain the moving average impact matrix of y_{it} as C_i. For large T, our model can be approximated as follows

$$y_{it}=C_i(\mu_i+\delta_i t)+C_i(L)(\lambda_t+\varepsilon_{it})+Z_i \tag{7}$$

where $C_i(L)$ is the coefficients of the lag polynomial, that is, $C_i(L)=C_{0i}+C_{1i}L+C_{2i}L^2+C_{3i}L^3+\ldots$, and Z_i depends on initial values, that is $Z_i=C_i(y_{i0}-\Gamma_{1i}y_{i1}-\Gamma_{2i}y_{i2})$.[6] As to Z_i, $\beta_i' Z_i=0$. For equation (7), Johansen's results provide the explicit values of C_i . Let $\alpha_{\perp i}$ and $\beta_{\perp i}$ be (2×1) orthogonal matrices to α_i and β_i such that $\alpha'_{\perp i}\alpha=0$, and $\beta'_{\perp i}\beta=0$. Using them, the moving average matrix (C_i) is obtained as follows.

$$C_i=\beta_{\perp i}(\alpha'_{\perp i}(I-\Gamma_{1i}-\Gamma_{2i})\beta_{\perp i})^{-1}\alpha'_{\perp i} \tag{8}$$

On the other hand, $C_i(L)$ and the initial conditions are implicitly obtained by Johansen's results (1991) and (1996).[7] For test of the neutrality hypothesis in our model framework, we only need the explicitly estimated values of C_i.

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6 L is the lag operator, where $C_{il}L^l=C_{it-1}$.

7 It is possible to obtain the explicit values of C_i (L) and Z_i following Hansen (2000). But it is not carried out in the current study because it is not needed.

In equation (7), the (1, 2) element in C_i matrix is $c_{12(i)}$, and the long run impact of exports on labour productivity or TFP. This effect is analogous to the estimated effect in cross-country growth regression using demeaned data. As to the relation between C_i and Π_i in our model, there is the following.

$$C_i = (\alpha'_{\perp i}(I - \Gamma_{1i} - \Gamma_{2i})\beta_{\perp i})^{-1} \begin{bmatrix} -\pi_{22(i)} & \pi_{12(i)} \\ \pi_{21(i)} & -\pi_{11(i)} \end{bmatrix} \tag{9}$$

In Equation (9), $(\alpha'_{\perp i}(I - \Gamma_{1i} - \Gamma_{2i})\beta_{\perp})$ is a scalar. Thus, Equation (9) clearly shows the notion of neutrality; if $\pi_{12i}=0$, then $c_{12(i)}=0$. In this case, we find no long run impact of export on labour productivity or TFP levels. It implies that the results of testing causality from cross-country growth regression using averages and time series approaches using annual data are possibly different. The former is testing neutrality while the latter is testing causality. For the relation between them, only is it directly said that Granger non-causality indicates neutrality.

In the cointegrated VAR model, the neutrality test can still rely on the significance of parameters of autoregressive representation since a zero-row in Π_i is corresponding to a zero-column in C_i. Therefore, if exports are neutral with respect to the long run level of labour productivity or TFP, then $\alpha_{2i}=0$. It also indicates that $\pi_{21(i)}=\pi_{22(i)}=0$ and $c_{11(i)}=c_{21(i)}=0$. On the other hand, the interpretation of neutrality tests is a bit different from that of the stationary VAR model. For example, we cannot conclude that exports have no long run impact on labour productivity or TFP levels although the neutrality of exports is statistically accepted. In such a case, the result says that per capita export carries no information about labour productivity or TFP.

4. Data

Our data consists of 28 Chinese provinces including the three municipalities (Beijing, Tianjing, and Shanghai) between 1988 and 2002.[8] Due to absence of data, Hainan and Tibet are excluded.[9] Output and labour statistics are available from various issues of national and provincial statistical yearbooks. The implicit GDP deflators are constructed by GDP at the current yuan (RMB) and volume indices at comparative (quasi-constant) prices which are obtainable from Huesh and Li (1999) and various issues of China's Statistical Yearbook as well. Exports data is from Huesh and Li (1993), "China Regional Economy" (1995) and various issues of China's Custom Statistics. The real exchange rates are available from the World Bank and the Asian Development Bank.

In addition to them, we construct the series of TFP by ourselves because the TFP statistics are not officially provided. In this study, TFP is measured from Cobb-Douglas production function as follows.

$$\log TFP = \log GDP - \theta \log K - (1-\theta) \log L \tag{10}$$

[8] Chongqing is included in Sichuan.

[9] The shares of their population and GDP are less than 1 percent in national total.

where θ is estimated using a two-way fixed effects model of provincial panel data following Fleisher, Li, and Zhao (2005).[10] In estimating TFP, annual shocks are controlled to be identical across provinces using a dummy variable for each year. On the other hand, we do not include a dummy variable for each province because it is thought that the dummy variable possibly eliminates a large part of exogenous variation of labour inputs. Instead, we add slope dummy variables for regions.

5. Empirical Results

This section focuses on the empirical results. At first, we have to test panel unit roots and cointegration because we use annual data of labour productivity, TFP and per capita export which are generally thought to be non-stationary. Tables 1 and 2 show the results of panel unit root tests and cointegration tests using the logit method. As we briefly described, we undertook Johansen's LR tests province by province. And then, the bootstrap approach proposed by Ahlgren and Antell is applied to generate the small sample critical values because Johansen's LR test has been reported to suffer a small sample bias. Using the obtained logit of probability for each province, we construct the test statistics of unit root and cointegration by equation 1. In the empirical analysis of this chapter, the number of provinces is 28 ($N=28$), and the time series data cover 25 years ($T=25$) during the period, 1978–2002.

In panel unit root tests, the null hypothesis for the series in first differences is a unit-root without drift against an alternative of mean stationary. The models include two lags. For series in levels, the null hypothesis is a unit root with drift against an alternative of trend stationary. The models include three lags. The results of unit root tests indicate that the null hypothesis in each of three series in first differences is rejected while that of the levels is not rejected. Thus, we conclude that the series in first differences are mean stationary.

Table 2 reports the results of cointegration in the two models. In both models, the hypothesis no

Table 1 Panel Tests for Unit-Roots in the Series

	First Differences			Level		
	dLP	**dTFP**	**dPcEXP**	**LP**	**TFP**	**PcEXP**
logit p	-5.71	-6.66	-6.66	1.10	0.84	-0.89
***p*-value**	0.00	0.00	0.00	0.27	0.40	0.38

Table 2 Panel Tests for Cointegration

	Model for LP and PcEXP		Model for TFP and PcEXP	
	2 unit roots	**1 unit root**	**2 unit roots**	**1 unit root**
logit p	2.16	0.30	2.89	-0.18
***p*-value**	0.032	0.761	0.004	0.858

[10] K and L are capital and labour. Here, K series is constructed applying the perpetual inventory method where the initial value of K is estimated as follows Chou (1995).

cointegration (=two unit roots) is rejected while the hypothesis of one unit root is not rejected. Thus, we conclude that there exists one cointegration vector in each model. Since there is a cointegration in each model, we discuss the long run relation between productivity and export from equation 5.

Tables 3 and 4 show the results of the Granger causality tests. In Table 3, the dependent variable is the log of labour productivity while is the log of TFP in Table 4. The estimation is conducted by the mean group (MG) estimator proposed by Pesaran and Smith (1995), in order to allow heterogeneity in the dynamic panels.[11] Using the results of the estimation for each province, the MG estimator and its t-statistics are obtained as follows. Here, $\hat{\beta}_i$ denotes the estimate of i-th individual province.

$$\hat{\beta}^{MG} = \bar{\beta} = \frac{1}{N}\sum_{i=1}^{N}\hat{\beta}_i \tag{11}$$

$$t_{\beta,MG} = \sqrt{N}\,\frac{\hat{\beta}^{MG}}{\sqrt{\sum_{i=1}^{N} V\hat{a}r(\hat{\beta}_i) \Big/ N}} \tag{12}$$

From equation (11), the estimated elements of the mean group Π matrix are also the average of the province-specific estimates. Thus, the Π matrix doesn't have reduced rank although the individual province specific Π_i matrix does. Equation (12) means that the covariance matrix of the mean group estimators is the average of the variances of the individual estimates. Since this average preserves the property of the variance of the individual Π_i matrix, the row-wise elements of Π matrix have identical t-values as well as individual Π_i matrix.[12]

As seen from Table 3, in the system [log(*LP*), log(*PcEXP*)], we detect bi-directional Granger causality between labour productivity and per capita exports at the five percent significance level. Statistically, Granger causality from exports to labour productivity seems to be more robust. In this discussion, one problem is that the notion of Granger causality is dependent on the frequency of observations. As Tiao states (1999), "if the data are observed at intervals when the dynamics are not working properly, then we may not find any kind of causality." Investigating Granger causality using annual frequency data may suffer this temporal aggregation problem. Because of data availability, it remains unsolved in many empirical studies on developing countries.

[11] Weinhold and Nair-Reichert (2001) also proposed an approach to allow heterogeneity in dynamic panels, called the Mixed Fixed and Random coefficient approach (MFR).

[12] In many papers of the mean group estimator including Pesaran and Smith (1995), the standard error is estimated as follows.

$$se(\hat{\beta}^{MG}) = \sigma(\hat{\beta}_i)/\sqrt{N}$$

where

$$\sigma(\hat{\beta}_i) = \sqrt{\sum_{i=1}^{N}(\hat{\beta}_i - \bar{\beta})^2 \Big/ (N-1)}$$

In both approaches, the estimated standard errors are consistent. But equation (12) is better because it converges faster.

Table 3 VECM1: Labour Productivity and Exports

Coefficient	dLP	dPcEXP
dLP1	0.350	-0.087
	(7.430)	(0.380)
dLP2	0.007	0.646
	(0.146)	(2.920)
dPcEXP1	-0.010	-0.012
	(0.836)	(0.272)
dPcEXP2	-0.001	-0.153
	(0.110)	(3.678)
LP1	-0.248	-0.231
	(7.873)	(1.239)
PcEXP1	0.037	-0.372
	(7.873)	(1.239)
Granger	0.000	0.025
Neutrality	0.000	0.233

t-values are in parenthesis

Table 3 also indicates that the coefficients on the levels are significantly estimated in labour productivity regression but not in per capita export regression. This means that the neutrality hypothesis is not rejected in the latter.

As we mentioned above, the VAR-model results are connected with that of averaged cross section results. For this purpose, we calculate the non-zero off-diagonal elements of the moving average impact matrix C from equation (9). The mean group estimate of c_{12} is 0.0578. It indicates that the one percent increase in per capita export leads to 5.78 percent increase in labour productivity in the long run. This result strongly support their export oriented strategy.

Adding to labour productivity, we also examine the system [log(*TFP*), log(*PcEXP*)] using the same framework. The reason of it is that neither labour productivity nor TFP is dominant as a measure of productivity. Sargent and Rodriguez (2001) argue this issue and conclude that labour productivity is more reliable in the short run while TFP the more useful in the long run, based on properties of the underlying growth process and capital stock data.[13] To enhance the robustness of our study, we examine both of them.

Table 4 gives us the result of VECM using TFP instead of labour productivity. The statistical inference from the estimation result is similar to that of the labour productivity system. The Granger non-causality hypothesis is rejected in the system of TFP and per capita export while the neutrality hypothesis is accepted in the per capita export equation. Thus increase in per capita export leads increase

[13] In their discussion, they define labour productivity as output per hour while we use output per worker.

Table 4 VECM2: TFP and Exports

Coefficient	dTFP	dPcEXP
dTFP1	0.275	-0.226
	(5.840)	(0.867)
dTFP2	-0.082	0.752
	(1.794)	(2.955)
dPcEXP1	-0.009	0.004
	(0.873)	(0.085)
dPcEXP2	0.003	-0.129
	(9.367)	(3.220)
TFP1	-0.169	0.115
	(5.600)	(0.806)
PcEXP1	0.028	-0.386
	(5.600)	(0.806)
Granger	0.000	0.001
Neutrality	0.000	0.432

t-values are in parenthesis

in the level of TFP in the long run, but not vice versa. We calculate non-zero off diagonal elements of the impact matrix *C* as well. The mean group estimate of c_{12} is now 0.125. It means that one percent increase in per capita export now leads to 12.5 percent increase in TFP. Although it is strongly supportive for their open-door policy, it casts doubt on the reliability that effects of export on TFP is more than twice as high as that on labour productivity.

One of the possible reasons to obtain such high impact is that there are some extreme outliers. From equation (11), the mean group estimator is influenced by them in the sample of a small amount of individuals. Table 5 shows provincial estimates of c_{12} in the impact matrices. Obviously, Heilongjiang province has an extreme estimate (2.252) in the system of TFP and export per capita. If we exclude Heilongjiang province from our panel, the mean group estimate of c_{12} for both labour productivity and TFP systems are respectively 0.0669 and 0.0464.[14] That is, one percent increase in per capita export leads to 6.7 percent and 4.6 percent increase in labour productivity and TFP. From definition, the growth of TFP doesn't include output growth from increasing capital. Thus this result is more reasonable.

As mentioned above, theoretical models give us some implications of the heterogeneous effects of trade on productivity growth. To discuss this, the provincial estimates of export impact, c_{12}, are also used. Using simple graphical analysis, figures 1 and 2 indicate that there are some outliers.[15] Here the

[14] Both are statistically significant at five percent significance level.

[15] In both figures, Heilongjiang is eliminated.

Table 5 Long Run Impacts of Export for Individual Provinces

Province	LP	TFP	Average	growth	Regions
BJ	0.043	-0.047	7891.22	7.34%	Eastern
TJ	0.673	0.325	6919.52	7.84%	Eastern
HE	0.040	0.045	2731.93	8.66%	Central
SX	-0.012	-0.034	2498.76	7.20%	Central
NM	-0.009	-0.093	2503.78	8.30%	Western
LN	0.140	0.119	4616.16	7.53%	Eastern
JL	0.084	0.052	2898.69	8.24%	Central
HL	-0.188	2.252	4096.62	6.61%	Central
SH	0.310	0.096	11757.70	7.59%	Eastern
JS	0.473	0.260	3961.08	10.59%	Eastern
ZJ	0.248	0.073	4164.89	11.35%	Eastern
AH	-0.146	-0.132	2099.78	8.71%	Central
FJ	-0.072	0.392	3534.20	10.88%	Eastern
JX	0.052	0.015	1956.41	8.53%	Central
SD	0.140	0.046	3245.04	10.01%	Eastern
HA	-0.014	0.070	2100.06	8.77%	Central
HB	-0.094	-0.086	2709.45	8.78%	Central
HN	-0.180	-0.061	2389.87	7.54%	Central
GD	0.207	0.181	3933.43	10.48%	Eastern
GX	-0.103	-0.117	2044.13	7.70%	Western
SC	0.121	0.042	2081.64	8.06%	Western
GZ	0.015	-0.018	1280.49	7.17%	Western
YN	-0.010	0.213	1973.83	7.13%	Western
SN	0.035	0.024	1915.27	7.71%	Western
GS	-0.129	-0.048	1619.19	7.17%	Western
QH	0.009	-0.020	2698.18	6.07%	Western
NX	-0.008	-0.032	2466.73	6.95%	Western
XJ	-0.010	-0.011	3117.18	7.86%	Western
East	0.235	0.256	4362.55	9.64%	
Centre	-0.050	-0.028	2525.53	8.12%	
West	0.016	-0.006	2028.98	7.72%	

Note: East, Centre, and West denote the weighted regional averages

points, 1.0, 2.0, and 3.0 on the horizontal coordinate indicate the eastern, the central and the western regions. In figure 1, Tiangjing and Jiangsu are much higher than others in the eastern region. In figure 2, Fujian, Tianjin and Jiangsu in the eastern region and Yunnan in the western region are also much higher than others in their own regional groups. Among them, Tianjin is not statistically different from the overall mean. The mean group estimate falls in the 95 percent confidence band for Tianjing while it is just outside the confidence band for Jiangsu, Fujiang and Yunnan. The higher impact in Tianjin might be from the fact that Tianjin is a port city.

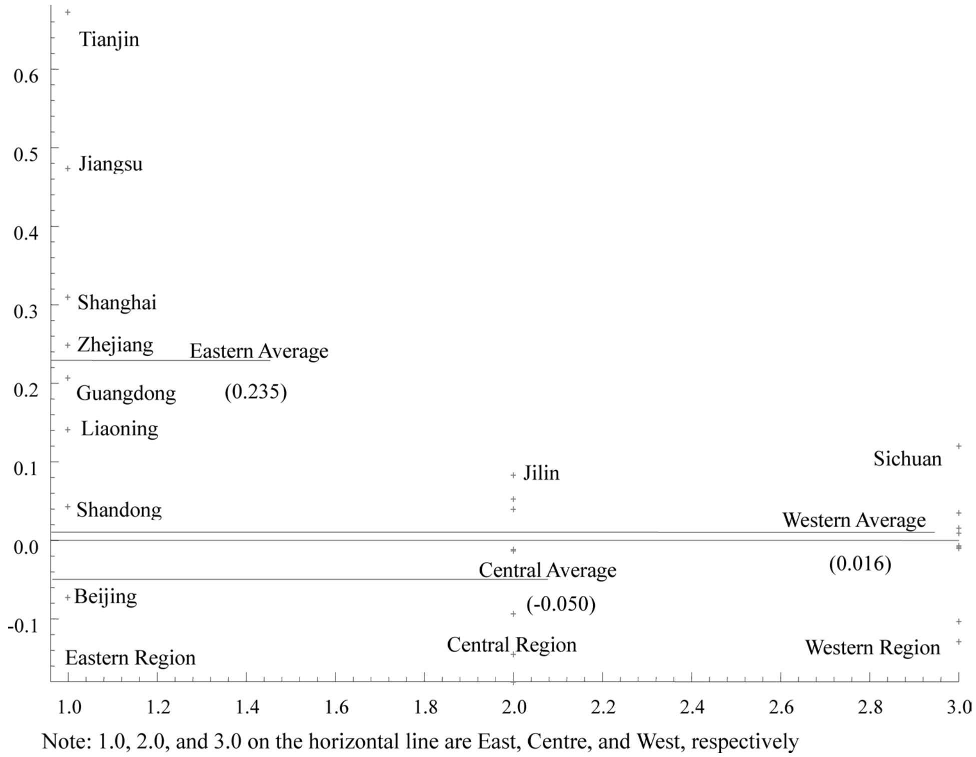


Figure 1 The Long-Run Impacts of Export on Labour Productivity

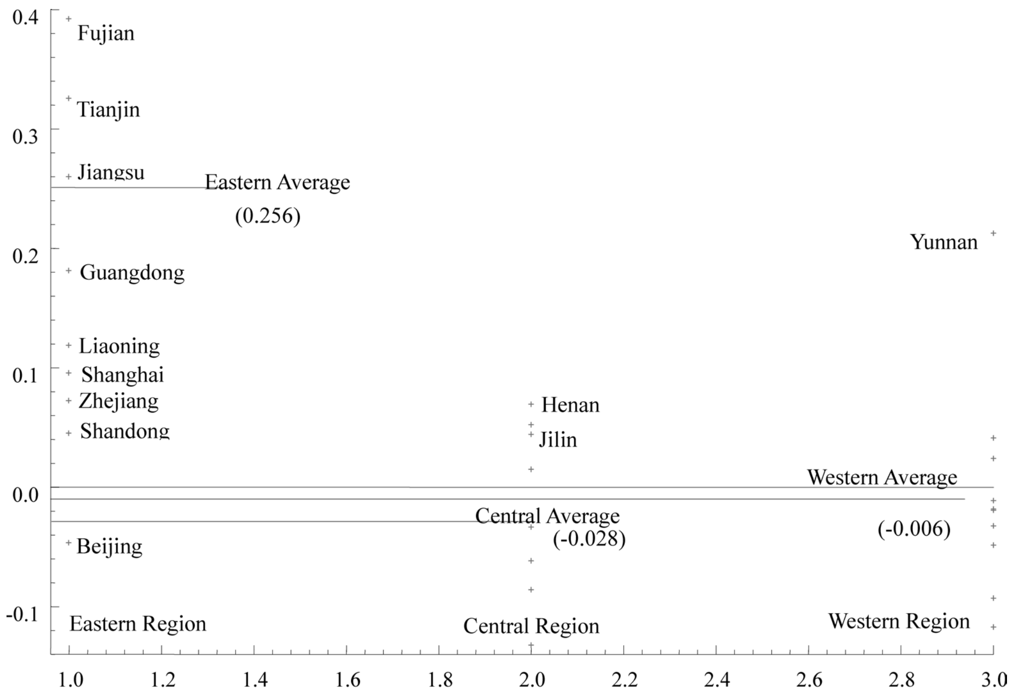
Figures 1 and 2 also give us the information of regional differences.[16] Interestingly, the eastern region obviously has a larger impact of exports on productivity than others. Thus, in China, exports have a higher positive long run impact on productivity growth in the eastern coastal provinces but not necessarily in the inland regions. For this issue, it is of interest to investigate if the impact varies with some theoretically induced factors or indicators of development.

As we discussed in the previous section, theoretically, differences in the components and partners of trade form heterogeneous effects of learning-by-doing. Trade of goods with better learning characteristics and trade with technologically more endowed partners are thought to increase the effects of learning. In empirical studies, the former condition indicates that trade of manufactured products has larger effects than that of rudimentary products.[17] On the other hand, the latter implies that trade with the advanced countries are more advantageous than trade with the less developed countries.[18] Other than these conditions, the levels of human capital are usually expected to have positive correlation

[16] The regional averages in both figures are weighted by labour and TFP, respectively.

[17] The rudimentary products in China's statistics roughly cover foods, beverages, non-food materials, minerals, and food materials.

[18] Chuang (1998) also finds the case that trade with countries whose technology levels are similar but slightly lagging behind also fosters learning effects.



Note: 1.0, 2.0, and 3.0 on the horizontal line are East, Centre, and West, respectively

Figure 2 The Long-Run Impacts of Export on TFP

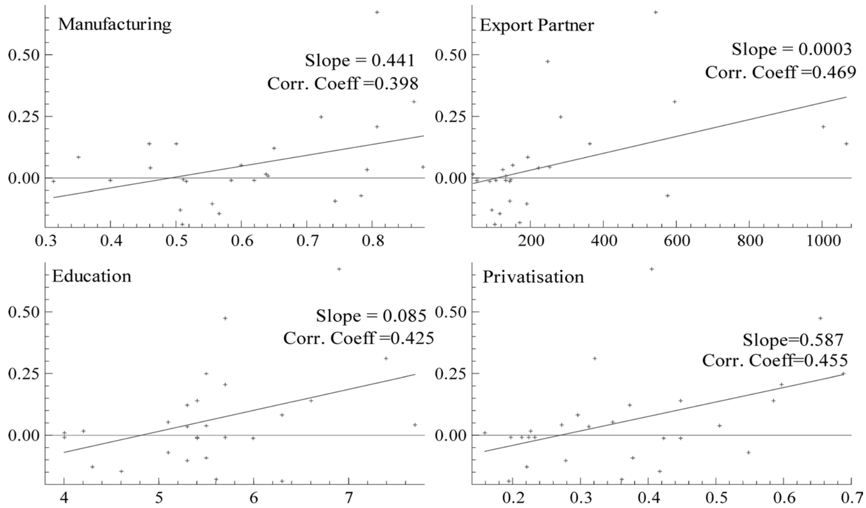
with learning effects. In addition, the degree of privatisation is possibly linked to learning effects through intensifying competition and following comparable advantage in the transition economies like China.[19]

One of the difficult problems of this issue is in data availability. In the case of China, provincial data of their trade components and partners are not always available before 1990 even in their official statistics. In addition, the characteristics of provincial trade have drastically changed over the last two decades. It implies that the averages of trade components and partners during the period are not always appropriate proxies. Here, we use data of the year 1990 because this year is the midpoint of the examined period of our study. Data of export of manufactured products in 1990 are available for 26 provinces.[20] Data of export partners are also available for 27 provinces. From Chuang (2002), we construct the export-induced learning variable (EL_i) as follows.

$$EL_i = \sum_j w_j (PCGDP^j - PCGDP^i) \quad \text{with} \quad w_j = \begin{bmatrix} \dfrac{Export_{ij}}{GDPi} & if\ PCGDP^j > PCGDP^i \\ 0 & if\ PCGDP^j \le PCGDP^i \end{bmatrix} \tag{13}$$

[19] We also examined the income gaps between rural and urban residents, and detected a poor correlation between them. But that is no carried in this thesis.

[20] Data of Jiangsu and Henan are not available.



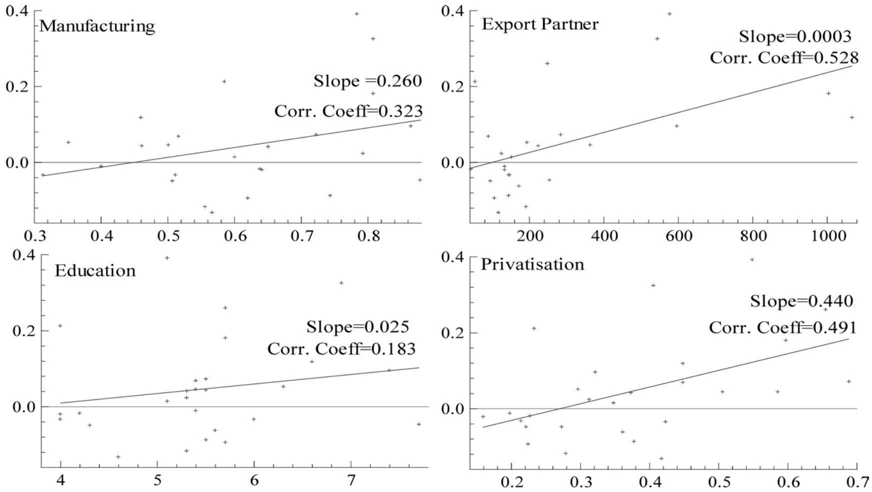
Note: In all graphs, the vertical coordinate is the long run impact of labour productivity

Figure 3 Labour Productivity and Four Indicators

where $Export_{ji}$ represents export of i-th province to country j, $i=1, \dots, 27$. As to the other two indicators, educational attainment is widely used as a proxy of the human capital level, and the privatization level is represented by the industrial output in private sectors as percentage of total industrial output. For both of them, data in 1990 are used.

In Figures 3 and 4, we are plotting the long-run effects for each province, against those indicators which represent provincial characteristics. As expected, all indicators are positively related to long run impacts on both labour productivity and TFP. In addition, for all indicators, the slope coefficients are smaller in TFP plots. It is consistent with the result of the mean group estimators. For individual indicators, the interactions with the long run impacts are not homogeneous. The ratio of manufacturing export to total export is not highly correlated with the long run impact. Some provinces whose ratios of manufacturing export are in the middle or even highest groups suffer the negative long run impacts. On the other hand, the correlations the export-induced learning variables (EL_i: trade partners) and the long run impacts are relatively higher. Except for Fujian in labour productivity analysis, provinces with larger EL_i have the positive long run impacts while most of provinces with low EL_i suffer the negative or almost zero long run impacts.

These two indicators are from Chuang's model implications. For our data, the implication of his model seems to give a better explanation to effects from trade partners than trade components. However, for provinces with lower EL_i, Young's implication is more reasonable because they have negative impacts. Thus, for Chinese provinces, Chuang's trade partner effect seems to be detected for the coastal provinces while inland provinces do not always enjoy the long run positive effects from export. One reason that manufacturing export has poorer explanatory power is in properties of this indicator.



Note: In all graphs, the vertical coordinate is the long run impact of TFP

Figure 4 TFP and Four Indicators

During our data period, in particular in the 1990s, their trade components have drastically changed. The shares of manufacturing export to total export are largely different in inland provinces between 1990, 1995, and 2000. Thus, the data of 1990 does not always represent their overall properties. However, the same analysis using different years gives us similar results. Thus, we conclude that our result using data of 1990 is reliable to some extent.

The correlation between education and the long run impacts are significantly lower in the case of TFP. This seems to have no correlation with the long run impacts. On the other hand, the relation between privatisation and the long run impacts is more homogeneous between labour productivity and TFP. As a result, privatisation has better explanatory power than education attainment. However, it doesn't mean that increasing education attainment has no meaning in increasing the long run impacts of exports on productivity. At least, provinces with the lowest education attainment are correlated with lower or sometimes negative long run impacts on labour productivity. Thus, increasing educational attainment is also necessarily to avoid negative long run impacts.

Although it is true that our analysis suffers from the problems of the small sample size, it reveals that there exist regional gaps in the long run impacts of exports. It also indicates that trade partners and privatisation are correlated with the impacts to some extent. Our results seem to support Chuang's implication for the coastal provinces while not always for the inland regions.

6. Concluding Remarks

From the estimation results, we draw the following conclusions. For the economic reform period between 1978 and 2002, increases in per capita exports contribute to increasing productivity at the national level in China. Productivity and per capita export have bidirectional Granger causality while the long run impact is found only from exports to productivity. In that sense, we conclude that exports cause productivity growth. Eliminating one extreme outlier, Heilongjian, export effects on labour productivity is higher than that on TFP as mean group estimates. This result may imply that export has positive effects through investment.

Based on our results, we discuss implications of some theoretical models of trade and growth. From Chuang's model, export components and partners are investigated as factors to form varying long run impacts of export. The simple graphical analysis reveals that differences of trade partners explain varying long run impacts between the coastal and inland regions to some extent. On the other hand, it is difficult to explain the heterogeneous long run impacts from differences of trade components in our results. Privatisation is also positively correlated with the long run impacts while the poorer educational attainment seems to be related to the lower export impacts in the long run. Thus our results are consistent with the implication of the theoretical models that trade with advanced countries contributes to productivity growth through learning and also consistent with the conventional view that poorer education and privatisation may work as a bottleneck in trade (export) induced growth.

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