Using A Trade-induced Catch-up Model to Explain China's Provincial Economic Growth 1978-97*

Yudong Yao†

Faculty of Economics and Politics, University of Cambridge

Johan Lyhagen

Department of Economic Statistics, Stockholm School of Economics

Stockholm School of Economics

Working Paper Series in Economics and Finance, No.435

Abstract

This paper attempts to make an innovative contribution to the growth literature by proposing a trade-induced catch up model in which imitation benefit is explicitly modelled and trade knowledge spillover is considered.

*Financial support for Lyhagen from The Swedish Foundation for International Cooperation in Research and Higher Education (STINT) is gratefully acknowledged. He is also Grateful to Prof. M. H. Pesaran who acted as his sponsor at his Post-Doc stay in Faculty of Economics and Politics, University of Cambridge.

†Corresponding author: Faculty of Economics and Politics, University of Cambridge, Sidgwick Avenue, Cambridge, CB3 9DD, UK. Phone: +44 1223 517792, E-mail: yy204@hermes.cam.ac.uk.

The resulting income dynamics is in the error correction form. The Pooled Mean Group dynamic heterogeneous panel data estimator (Pesaran and Shin, 1997) is used to empirically implement the error correction catch-up dynamics. The application is to China's provinces during the reform period 1978-97. The main findings are: there is a positive long-run relationship among per capita GDP, per capita capital and per capita trade, which can account for China's economic growth miracle during the last two decades. Moreover, the trade knowledge spillover benefits disproportionately to individual provinces and thus cause significant differences of growth growth across the provinces.

JEL: F14; O11; C22; C23

Keywords: Growth; dynamic panel

1 Introduction

Since China adopted the reform and open-door policy in 1978, the annual growth performance of China's provinces have been extraordinary and can be comparable to the East Asia Miracle. Table 1 shows that the average annual growth rate of real per capita GDP of all provinces during the reform period 1978-97 is 9.09%. However, average annual growth rates over the last two decades of the reform period vary significantly across the provinces. In particular, the slowest-growing province, Qinghai, only grows at an annual average of 5.88% while it is a respectable growth rate for any other economy or region in the world. The second slowest-growing province is Heilongjiang, a heavy industry base in the north-east of China, which grows at 6.70%. Qinghai's and Heilongjiang's growth performances stand as a sharp contrast to five coastal provinces which have managed to grow at two digit numbers. These provinces are Jiangsu, Zhejiang, Fujian, Shandong and Guangdong, with the average annual growth rates over 1978-97, respectively, given by 12.33%, 13.27%, 12.64%, 10.83% and 11.51%. We call these five provinces as "five dragons" in due course.

"East Asian Growth Miracle" has attracted a great deal of interest in the economic profession (e.g. Young, 1991, 1995). Likewise, it is an interesting question to ask why China's provinces especially the five dragons have grown so fast and why they are different in terms of the long-run economic growth rate.

As Stiglitz (1994) points out, "The most reasonable (and logically consistent) interpretation of the cross section growth observations, in particular, the rapid growth of the countries of East Asia, is that it entails a process of catching up to the technology of the more advanced countries." The primary purpose of this paper is to use a new trade-induced catch-up model to examine province-specific long-run effects of trade and carry on a relatively crude growth accounting to identify the different growth sources at China's province level during the reform period 1978-97.

In particular, the traditional catch-up hypothesis has evolved over the decades through the contributions of Veblen (1915) and Gerschenkron (1962). The catch-up hypothesis says that countries that are technologically backward have a potential for generating growth more rapidly than more advanced countries through technological imitation[1]. Most of the existing catch-up models (see, for example, Nelson and Phelps, 1966; Benhabib and Spiegel, 1994; Bernard and Jones, 1996) assume that the catch-up process follows the partial adjustment mechanism. With this mechanism, the catch-up dynamics for an economy can be stated as: *Growth rate of technology levels (measured by labour productivity or TFP) equals the speed of catch-up times percentage gap to its own steady state.* It implies that the growth rate of the economy is proportional to the gap between the economy's current technology level and its steady state position.

However, one major shortcomings of the existing catch-up models are that they fail to model imitation benefit. As a response, we propose a trade-induced catch-up model in which imitation benefit is explicitly considered. The main advantage of this model is that it resulting catch-up dynamics is an error correction model (ECM), which has become a very popular empirical specification for dynamic equations in applied economics, including applications to such important problems as consumption, investment, and the demand for money[2].

[1] Abramovitz (1986) also argues that there exists some minimum level of development below which the country is not capable of absorbing new technologies and the mere existence of a technology gap is not a guarantee for faster growth. This is a so-called "social capability".

[2] Discussion and references are contained in Hendry, Pagan and Sargan (1984)

Specifically, the ECM statistical framework is attractive, in that it encompasses models in both levels and differences of variables and is compatible with long-run equilibrium behavior. Also, it is consistent with the concept of cointegration in economic time-series (Granger and Engle, 1987). Moreover, the ECM framework in the panel data setting can be estimated by the Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (1999), which has advantages over other panel data estimator such as the Within Group and first-difference GMM estimators in allowing for parameter heterogeneity.

This empirical application to China's provincial trade-growth relationship provides important policy implications for the on-going policy debate in China on the World Trade Organization (WTO) membership issue. There is strong debate within China on lower tariff rates required by its major trading partners such as USA and European Union, presumably prerequisites for a WTO membership.

This paper is organized as follows: Section 2 briefly review the existing technology catch-up models, Section 3 presents a simple new theoretical framework, i.e. a trade-induced catch-up dynamics. The solution of this model turns out to be in the ECM form. Section 4 discusses the empirical method of panel data with a focus on the PMG estimator. Section 5 reports and discusses the empirical results. Section 6 gives the conclusion.

2 An Overview of the Catch-up Models

The traditional catch-up hypothesis doesn't specify how a technologically backward country can catch up a technologically advanced one. The form modelling of the catch-up dynamics started from the work of Nelson and Phelps (1966).

They assume a partial adjustment mechanism for the catch-up process. Suppose that the growth of technology A_t, or the labor productivity, depends on the gap between its current level A_t and the level of 'theoretical knowledge', E_t:

$$\dot{A}_t = \omega(H)\left[E_t - A_t\right] \tag{1}$$

The rate at which the gap is narrowed depends upon the level of human capital, H, through the function, $\omega(H)$, where $d\omega/dH > 0$ and $E_t > A_t$. In Nelson and Phelp's model, the level of theoretical knowledge *exogenously* grows at a constant exponential rate, such that $E_t = E(0)e^{\lambda t}$. The solution to the differential equation (1)

$$A_t = \left(A_0 - \frac{\omega(H)}{\omega(H)+\lambda}E_0\right)e^{-\omega t} + \frac{\omega(H)}{\omega(H)+\lambda}E_0 e^{\lambda t} \tag{2}$$

This equation implies that the steady state technology level A_t^* is given by

$$A_t^* = \frac{\omega(H)}{\omega(H)+\lambda}E_0 e^{\lambda t} \tag{3}$$

The equilibrium gap is given by

$$\frac{E_t - A_t}{A_t} = \frac{\lambda}{\omega(H)} \tag{4}$$

In a technologically stagnant economy ($\lambda = 0$), the steady-state error approaches zero for every $H > 0$. In a technologically progressive economy ($\lambda > 0$), there is a positive steady-state error for every $H > 0$. The steady-state error is increasing in λ and decreasing in H. In the short run, the rate of growth of productivity is a function of human capital and the productivity gap, but in the long run it grows at the rate λ.

However, there are several problems with the technological catch-up models. First, the core of the catch-up hypothesis is the belief that technological imitation is cheaper than technological innovation, while most existing catch-up models (e.g. Bernard and Jones, 1996) fail to model imitation benefit[3].

3 A Trade-induced Catch-up Framework

The setting of our catch-up model is a two country (North-South) relation. We assume that one of the two countries (the North) is a technologically advanced economy while the other one (the South) is less developed. The North and the South trade with each other and the trade (exports and imports) is always balanced. We assume that the North's more advanced technology is embodied in commodities traded between the North and the South and spreads to the South. The South does not invent technology, but instead imitates or adapts the more advanced technology of the North.

We further assume that the South has a single sector. Consider a representative firm in this sector facing perfect market competition. Each firm in the sector is risk neutral, acts competitively, and has rational expectations about the underlying stochastic processes of technology diffused in the sector and the decision rules of other firms. By trading with the North, the more advanced technology of the North has been diffused within the sector of the South. The

[3] Another drawback is a lack of formal modelling of the role of international trade in mediating the catch-up process so far while international-trade-mediated knowledge spillover has attracted increasing attention. For example, Abramovitz (1986) argues that international trade is one of the facilities for the diffusion of knowledge and link with a country's "social capability" to catch-up. Dollar, Wolff and Baumol (1988) suggest that there exists "strong circumstantial evidence that technology diffusion through trade in goods and international investment ... (has) played an important role in the convergence of productivity levels". Hence it would be useful to consider the role of trade in the catch-up modelling.

use of the new technology requires some effort for adaptation to a different environment under the competition pressure from the North and meanwhile gains some benefit from the imitation activities. Accordingly, we distinguish two types of cost incurred by the southern firms. (1) Market competition cost; (2) Adjustment cost. On the other hand, however, the cost of imitation is typically less than the cost of innovation (Barro and Sala-i-Martin, 1995). Compared with the market competition cost and adjustment cost, we think of imitation generally as a beneficial activity. Hence there is an imitation benefit enjoyed by the firms. Below we present some interpretations for the two costs and one benefit.

Market Competition Cost

Following Baumol (1986)[4], we assume that the firms in the South face competition pressures induced from the diffusion of the technology to the sector. Because of the competition pressure, every firm has to adopt the new technology as soon as possible for survival. The danger of postponing the date of technology adoption is that it may actually reduce the profit flow because a rival may decide to adopt the innovation during the delay. Griliches (1957) finds in U.S. regional data that the time at which hybrid corn is introduced and the rate at which this innovation spread depends on measures of the cost of absorption and the eventual profitability of the new technology. The faster the rate of absorption, the greater the market size and the larger the potential improvement in crop yields. Stoneman and Kwon (1996) use a model of diffusion of new

[4]Baumol (1986) argues that "There is reason to suspect that the pressures for rapidity in imitation of innovation in industrial countries have been growing......The penalties for failure to keep abreast of innovations in other countries and to imitate them where appropriate have grown."

process technologies to test the relationship between firm profitability and the adoption of technology on the data relating a sample of firms in the UK engineering industry during the period 1983-86. They find that they can not reject the hypotheses, that the profit gain of a non-adopting firm declines as other firms adopt new technologies. If a firm in the South refuses to adopt the more advanced technology, it will lose the competitive advantage in the market. The intertemporal market competition cost can be expressed as a myopic quadratic form

$$E(C_{M,t}) = \sum_{j=0}^{\infty} \delta^j \lambda_1 (y_{t+j} - y_{t+j}^*)^2 \tag{5}$$

where $C_{M,t}$ is the market competition cost for the firm at time t, $E(C_{M,t})$ is the expected cost of market competition, y_{t+j} represents the actual labour productivity of the firm in the South at time $t+j$, y_{t+j}^* is the desired or target labour productivity and represents the more advanced technology which the firm wishes to adopt at $t+j$, δ is a discount factor $(0 \prec \delta \preceq 1)$ and $\lambda_1 > 0$ is a constant coefficient.

Adjustment Cost

In order to adopt the new technology embodied by the North-South trade, the firm in the South has to adjust its existing production process. Thus this incurs the adjustment cost. We assume the adjustment cost C_A takes a quadratic form. The intertemporal adjustment cost can be expressed as

$$E(C_{A,t}) = \sum_{j=0}^{\infty} \delta^j (y_{t+j} - y_{t+j-1})^2 \tag{6}$$

where $C_{A,t}$ is the adjustment cost of the firm at time t, $E(C_{A,t})$ is the expected adjustment cost.

Benefit from Imitation Activities

The firm in the South benefits from the trade-embodied knowledge spillover and begins to imitate the new technology. Technology imitation activities incur cost and meanwhile return benefit. Whether the benefit from imitation is generally greater than the imitation cost or not requires some empirical support. Compared with cost resulting from innovation activities, there is empirical evidence suggesting that imitation cost is substantially lower. For example, Mansfield (1981) finds that the ratio of imitation costs to innovation costs in a sample of 48 product innovations is relatively low. Teece (1997) examines 26 international technology transfer projects and discovers that technology transfer costs averaged 19% of total project costs. Transfer costs are found to depend on a range of factors, including the age of the technology, the host industry's manufacturing experience, the number of firms already utilizing the technology and the capability and ease of the transfer. In particular, he suggests that a kind of learning process is involved in transferring technology. For example, in chemical and petroleum refining, the second start up of the same project lowered costs by 34% relative to the first start up, and by 19% for the third start up. Therefore, we can take imitation generally as a beneficial activity.

The benefit from imitation may be expressed in the form of $(y_{t+j}-y_{t+j-1})(y^*_{t+j}-y^*_{t+j-1})$. The intertemporal benefit from imitation activities for the Southern firm can be written as:

$$E(B_t)=\sum_{j=0}^{\infty}\delta^j\left[2\lambda_2(y_{t+j}-y_{t+j-1})(y^*_{t+j}-y^*_{t+j-1})\right] \tag{7}$$

where B_t is the imitation benefit. $E(B_t)$ is the expected imitation benefit. $\lambda_2>0$. The constant is normalized to 2 for the convenience of solution.

The term $(y_{t+j}-y_{t+j-1})(y^*_{t+j}-y^*_{t+j-1})$ is positive as long as the direction in actual labour productivity change $(y_{t+j}-y_{t+j-1})$ is consistent with the direction of the target labour productive change $(y^*_{t+j} - y^*_{t+j-1})$. However, this term becomes negative if the firm moves in the 'wrong' direction, i.e. the actual labour productivity change $(y_{t+j} - y_{t+j-1})$ does not follow the target change $(y^*_{t+j} - y^*_{t+j-1})$. This desired direction is exactly the feature of imitation activities because innovation activities normally are uncertain but imitation activities are quite sure in choosing the technological improvement directions. By contrast, all previous studies (e.g. Nickell, 1985; Domowitz and Hakkio, 1990) regard $(y_{t+j} - y_{t+j-1})(y^*_{t+j} - y^*_{t+j-1})$ as a counter-intuitive term and fail to offer an economic interpretation for it. For example, Nickell (1985) argue that "the last term[5] is unusual in the sense that it does not normally appear in models of this type. It is included because it has been suggested, in Hendry and von Ungern-Sternberg (1981) for example, that it has a legitimate role to play as part of an agent's objective.......it is inconsistent with sensible behavior at least with regard to the above problem." The contribution of the present study lies in the use of imitation benefit to explain this "strange" term.

We now combine two costs and one imitation benefit together. The total expected intertemporal cost of the technology adoption is given by:

$$E(C_t) = E(C_{M,t}) + E(C_{A,t}) - E(B_t) \tag{8}$$

or

$$\begin{aligned} E(C_t) \quad = \quad & \sum_{j=0}^{\infty} \delta^j \left\{ \lambda_1 (y_{t+j} - y^*_{t+j})^2 + (y_{t+j} - y_{t+j-1})^2 \right. \\ & \left. -2\lambda_2 (y_{t+j} - y_{t+j-1})(y^*_{t+j} - y^*_{t+j-1}) \right\} \end{aligned} \tag{9}$$

The second term is a standard quadratic adjustment cost on which we normalize. The firm is assumed to choose a sequence $\left\{ y^{\infty}_{t+j,j=0} \right\}$ so as to minimize

[5] That is $(y_{t+j} - y_{t+j-1})(y^*_{t+j} - y^*_{t+j-1})$

the expected value of C_t, conditional on information available at time t, subject to a law of motion for y_t^*. The intertemporal optimization solution of this intertemporal loss function is given by Nickell (1985). He shows that the steady state solution for this intertemporal optimization cost problem of the individual firm in the South can be simplified as an ECM as long as the target labour productivity y_t^* is non-stationary, which is supported by considerable evidence (Lee, Pesaran and Smith, 1997; Pedroni, 1997, 1999). For example, Lee, Pesaran and Smith (1997) use the IPS panel unit root test and find the presence of unit roots in per capita GDP for different groups of countries in the Summers-Heston (1995) data. Thus, it is reasonable to assume that the underlying stochastic process of the target labour productivity y^* of the firm in the South has a unit root. Following Nickell (1985), the optimal technology adoption or catch-up dynamics for the firm is in the ECM form as

$$\Delta y_t = a + b\Delta y_t^* + \omega(y_{t-1} - y_{t-1}^*) \tag{10}$$

where a is a constant, b is the short-run adjustment coefficient and ω is the speed of the adjustment process.

The South has only one sector and the firm under study is a representative firm, the aggregate catch-up dynamics of the South is the same as that of the representative firm.

Moreover, the existing catch-up models assume an exogenously growing labour productivity (or technology). Without knowing how technology advances, we are still incapable of identifying the underlying growth mechanism[6].

[6] Mainly because of a dissatisfaction with this puzzle, endogenous growth theory emerged in the middle of 1980s. This led to a construction of models where the determinants of growth are endogenous. Romer (1986) and Lucas (1988) are usually mentioned as the instigators of this new growth wave.

As such, we assume that the target labour productivity y_t^* follows an endogenous growth process. Similar to the spillover effect of human capital of Lucas (1988), we suppose that the aggregate production function of a representative economy has trade-embodied knowledge spillover effects and can be expressed as

$$Y_{it}^* = K_{it}^{\beta_i}[A_0 L_{it}]^{1-\beta_i} W_{it}^{\gamma_i} \tag{11}$$

where Y_{it}^* is the output, K_{it} is the provincial physical capital stock, L_{it} represents the provincial labour force. Grossman and Helpman (1991) have used the size of trade volumes as a proxy for the extent of knowledge spillovers between countries. Likewise, W_{it} is per capita international trade and reflects trade-embodied knowledge intensity of the province, $i = 1, ..., N$; $t = 1, ..., T$; A_0 is initial technology level. β_i $(0 < \beta_i < 1)$ and γ_i are constant parameters. $\gamma_i = 0$ means no effect of knowledge spillover and the aggregate production function is constant returns to scale. $\gamma_i > 0$ means that there is knowledge spillover in the provincial economy and the aggregate production function exhibits increasing returns to scale. There is a possibility that $\gamma_i < 0$, which implies a negative spillover effect and decreasing returns to scale. The knowledge spillover does not necessarily lead to the productivity gain in the economy.

Perhaps the most difficult issue is how to interpret the heterogeneity of spillover effects. A possible interpretation for the different spillover effects across the economies is that they depend on the different "familiarity" (Goodfriend and McDermott, 1998) to the trade-embodied foreign knowledge, which reflects the efficiency with which the knowledge can be acquired. According to Goodfriend and McDermott (1998), countries that promote familiarity with others find easier to acquire knowledge-how and will eventually catch-up to or even overtake the per capita income levels of more advanced trading partners. Less-developed countries that cannot increase their familiarity with the developed world will persistently lag world leaders. They use the familiarity to interpret "East Asian Miracle". For example, the Japanese growth miracle seems closely tied to increasing familiarity with the West. It began in 1868 with deliberate steps following the Meiji Restoration to adopt Western ways. The significant U.S presence in Japan immediately following the second World War and during the Korean and Vietnam Wars further familiarized Japan with developments outside of Asia. The protracted U.S. involvement in the Far East, especially in Japan and South Korea, may have helped lay the groundwork for the postwar growth miracles of the East Asia by familiarizing people in those nations with the United States.

Taking logarithms of equation (11) and adding in an error term yields

$$y_{it}^* = a_0 + \beta_i k_{it} + \gamma_i R_{it} + e_{it} \tag{12}$$

where $y_{it}^* = \log(\frac{Y_{it}}{L_{it}})$ is per capita output, $k_{it} = \log(\frac{K_{it}}{L_{it}})$ is per capita capital stock and represents capital intensity, $R_{it} = \log(W_{it})$, $a_0 = \log(A_0)$ is constant, e_{it} is an error term. Total factor productivity (TFP) can be calculated as $TFP_{it} = a_0 + \gamma_i R_{it} + e_{it} = y_{it}^* - \beta_i k_{it}$.

Substituting equation (12) into equation (10), we obtain a complete ECM catch-up dynamics

$$\Delta y_t = a + b_1 \Delta k_t + b_2 \Delta R_t + \omega \left(y_{t-1} - a_0 - \beta k_{t-1} - \gamma R_{t-1} \right) \tag{13}$$

where coefficients β and γ in equation (13) represent the long-run relationship among the actual labour productivity y_{t-1}, capital per capita k_{t-1} and trade per capita R_{t-1}. As can be seen by setting $b_1 = b_2 = 0$, the ECM dynamics conveniently nests the partial adjustment mechanism implied by many catch-up models.

The ECM equation (13) enjoys the success and popularity in the applied economics (Domowitz and Hakkio, 1990). In our context, an important and practical significance is that it can embody the long-run trade-growth relationship in terms of the trade knowledge spillover effects in a dynamic framework which can allow the business cycle effect. In particular, the adjustment speed ω could be less than -1 and thus involves overshooting. By contrast, the partial adjustment mechanism implied by the existing catch-up models involve no oscillations and is direct without the presence of overshooting. In reality, however, macroeconomics data such as per capita income has both the long-run growth effect and the business cycle effect. How to balance these two effects is an important empirical issue. As Romer (1986) points out "Because theories of long-run growth assume away any variation in output attributable to business cycles, it is difficult to judge the empirical success of these theories. Even if one could resolve the theoretical ambiguity about how to filter the cycles out of the data and to extract the component that growth theory seeks to explain, the longest available time series do not have enough observations to allow precise estimates of low-frequency components or long-run trends. When data aggregated into decades rather than years are used, the pattern of growth in the United States is quite variable and is apparently still influenced by cyclical movements in output."

The resultant ECM framework has remarkable flexibility in balancing the long-run trade-growth relationship and the short-run business cycle dynamics.

4 Empirical Method

With the emphasis on trade-embodied knowledge spillover and technological imitation activities, the trade-induced catch-up dynamic framework above can provide a common dynamics of the catch-up process for many similar economies like the South, given by equation (13). Based on this common dynamics, we use the panel data method to pool the data for the different economies together. Hence adding an error term and time trend to equation (13) yields

$$\Delta y_{i,t} = a_i + b_{1i}\Delta k_{i,t} + b_{2i}\Delta R_{it} + \omega_i \left(y_{t-1} - a_{0i} - \beta_i k_{i,t-1} - \gamma_i R_{i,t-1}\right) + T + u_{it} \tag{14}$$

where $u_{it} \sim N(0, \sigma_i^2)$ is the error term, $i = 1, 2, ..., N$ is the index for economies; $t = 1, 2, ..., T$ is time, also we define $\mathbf{b} = (b_1, b_2)'$ as the vector of the short-run coefficients, $\mathbf{z} = (k_{i,t-1},\ R_{i,t-1}\ )'$ as the vector of the regressors, $\mathbf{c} = (\ \beta_i, \gamma_i)$ as the vector of the long-run coefficients.

The various ECM panel data models in the literature can be viewed as restricted forms of the general specification (14), which contains a common dynamic specification but leaves the heterogeneity problem open. The primary difference between the various panel data estimators is the degree to which they impose homogeneity across provinces with respect to variances, short or long-run regression slope coefficients and intercepts. In this section we consider three estimators: the Mean Group (MG), the PMG (Pesaran, Shin and Smith, 1997) and the Dynamic Fixed Effect estimator (DFE). The three estimators (MG, PMG, DFE) are nested within the specification (14) with the restriction either on the dynamic specification or the homogeneity of error variance and/or the equality of short or long-run slope coefficients across the economies. The least restrictive procedure is the MG estimator. This imposes no homogeneity and is calculated as the mean (across the individual economy) estimates of the long-run, the short-run and adjustment coefficients[7]. The next least restrictive estimator is the PMG estimator which imposes equality of one or both of the long-run coefficients, **c**, but allows the short-run dynamics coefficients **b** and error variances to differ across the economies. Imposing these equality restrictions on **c**, if they are valid, will increase the efficiency and reduce the standard errors of the estimates.

Nonetheless, we might expect that the homogeneity restriction is not a all-or-none issue and some parameters in equation (14) may be common and some different[8]. In the short run, we might expect that every economy's catch-up process is very likely to be idiosyncratic with each other in terms of different short-run coefficients **b**. In the long run, however, we might expect that all provinces may share a common production function with trade knowledge spillover in terms of the same long-run coefficients **c**. In other words, we might suppose that **c** are more likely to be more homogenous than **b**. Comparing with the MG and DFE estimators, the potential advantage of the PMG is to concentrate on a common long-run growth relationship and meanwhile control for the short-run heterogeneity problem across the economies. Thus it can be seen as a balance between the MG and the DFE. Since the three estimators are nested with each other, we can detect how much parameter similarity there is and how much parameter dissimilarity there is in equation (14) by carrying out

[7]The standard error of MG estimate is calculated in exactly the same way as the standard error of the mean as the standard deviation of the individual coefficients divided by the square root of N.

[8]It is worthy noting that the adjustment speed can be different across the economies as well. Because our primary interest is to study the long-run effects of trade knowledge spillover on economic growth across China's provinces, this paper won't explore this issue further.

Likelihood Ratio (LR) test or Hausman test suggested by Pesaran, Shin and Smith (1999).

In particular, the restrictions of a complete long-run homogeneity implies that the long-run coefficients of capital stock and trade per capita are the same across the economies. Under this restriction, equation (14) becomes

$$\Delta y_{i,t} = a_i + b_{1i}\Delta k_{i,t} + b_{2i}\Delta R_{it} + \omega_i \left(y_{t-1} - a_{0i} - \beta k_{i,t-1} - \gamma R_{i,t-1}\right) + T + u_{it} \tag{15}$$

where $\beta_i = \beta$ and $\gamma_i = \gamma$ for all i.

If we only impose the long-run homogeneity on capital coefficients, namely, $\beta_i = \beta$ for all i, and allow the long-run trade coefficients to be different across all economies. Under this partial long-run homogeneity restriction, equation (14) becomes

$$\Delta y_{i,t} = a_i + b_{1i}\Delta k_{i,t} + b_{2i}\Delta R_{it} + \omega_i \left(y_{t-1} - a_{0i} - \beta k_{i,t-1} - \gamma_i R_{i,t-1}\right) + T + u_{it} \tag{16}$$

The DFE estimator imposes homogeneity on the long-run coefficients **c** as well as on the short-run coefficients **b** of (14), while the DFE estimator still allows variances to be different across the economies

$$\boldsymbol{\omega}_i = \boldsymbol{\omega}, \beta_i = \beta, \gamma_i = \gamma, b_{1i} = b_1, b_{2i} = b_2, i = 1, 2, ..., N \tag{17}$$

If we further impose equality of error variances, it is known as the Within Group estimator. Pesaran, Shin and Smith (1999) suggest that the variances are very likely to differ significantly across the economies. Provided that the assumption of equality of error variances is invalid, the Within Group estimate would be inefficient and the estimated standard errors would be biased and inconsistent.

5 Empirical Results and Analysis

Young (2000) argues that growing interregional competition between duplicative industries, threatened the profitability of these industrial structures, leading provincial and local governments to impose a variety of interregional barriers to trade. He finds compelling evidence to support the idea that interregional trade of China has been relatively restricted after 1978. For example, he observes a divergence in regional prices in the late 1980s, followed by fluctuating rounds of convergence and divergence during the 1990s. Given a fragmented and less developed domestic economy of China (Young, 2000), individual provinces may be seen as many independent developing "Southern" economies. During the reform period, individual provinces are actively trading with the technologically advanced "North" such as the OECD countries and East Asia economies (Naughton, 1996). Trade not only increases each province's knowledge stock but also may stimulate knowledge spillover within each provincial economy. Therefore, we can presuppose the trade-induced catch-up theoretical framework as the underlying economic growth mechanism of China's provinces. As such, the provinces share a common error correction dynamics of per capita income[9], which is represented by equation (13). Based upon this empirical specification, we can focus on the long-run trade-growth relationship, i.e. the trade-embodied knowledge spillover effect, at the province level using three alternative estimators, i.e. the MG, the PMG and the DFE, to estimate equation (13). The obtained long-run coefficients can be used to conduct a growth accounting analysis for the province-specific growth sources.

[9] Here we use per capita income to approximate per worker income (labor productivity) partially because provincial labor data is not complete for some provinces.

5.1 Data Issues

Our data set contains 28 economic provinces of China for a 45 year period (1952-1997). Provincial GDP data comes from the Hsuech and Li (1999) data set, covering the period 1952-95. Provincial GDP data for 1996 and 1997 is drawn from China Statistics Yearbook 1997. We use total population in combination with GDP and deflated by provincial GDP deflators, taking 1995 as the base year to generate real per capita GDP by province.

Hsuech and Li (1999) data set provides provincial investment from 1952 to 1995. Investment is referred to gross fixed capital formation at the current price. The calculation of gross fixed capital formation is based on the total social fixed asset investment which includes domestic investment and FDI. Provincial investment data for 1996 and 1997 is drawn from China Statistics Yearbook 1997. Investment is deflated by provincial investment deflators. The investment deflator takes the prices of 1995 as 100%. Hence we can get real provincial investment for the period 1952 to 1997. We construct the time series of capital stock from 1952 to 1997. The perpetual inventory method is employed to generate real capital stock each year. To work out the time series of capital stock, we need to know the average depreciation rate of capital and its initial level. According to Perkins' (1988) method, the overall depreciation rate is 5%. The initial capital stock in 1951 in each province is set to 3 times National Income in 1951, which is drawn from Hsuech, Li and Liu (1993) data set.

Provincial international trade includes real exports and real imports. Exports and Imports data at provincial level come from Hsueh, Li and Liu (1993) data set and various issues of China Statistics Yearbook. Real export volumes and real import volumes in dollars are obtained by using the export price index and the import price index from various issues of China Custom Statistics as deflators, respectively. Then real international trade in dollars is transformed to real international trade in Chinese currency (Yuan) by using the real exchange rates provided by World Bank.

5.2 Panel Data Testing for Unit Root

We apply the t-bar test of Im, Pesaran and Shin (1996, IPS) to three variables: per capita income, per capita capital stock and per capita trade. The null hypothesis of the IPS test is $H_0 : \beta_i = 0$ for all i against the alternative hypothesis $H_0 : \beta_i < 0$ for all i. The IPS t-bar test procedures[10] are that the ADF equation is estimated separately by OLS for each individual province and then pooling the individual ADF unit root t statistics of β_i, based on the ADF regression of order p_i, together by using the Central Limit Theorem to test the joint null hypothesis. It thereby allows for differing parameter values, residual variance and even different lag lengths and thus complete heterogeneity among individual provinces.

Table 2 presents the results. The t-bar test without trend cannot reject the null hypothesis of unit root for k_{it} and R_{it}. Furthermore, Table 2 reports that the t-bar test can reject the null for the first-difference variables Δy_{it}, Δk_{it}, ΔR_{it} at the 1% confidence level. Therefore, per capita GDP y_{it} , per capital capita k_{it} and trade R_{it} are $I(1)$.

[10] The IPS tests consist of another test statistic: LM-bar test. Given $N = 28$, $T = 26$ for the pre-reform period and $T = 20$ for the reform period, the simulation results of IPS for the similar panel data dimension shows that t-bar test has higher power than the LM-bar test. In this dissertation, we only present the t-bar test results. Nonevertheless, the LM-bar test results are consistent with the results of the t-bar test.

5.3 Alternative Estimates for the Long-run Coefficients

In this section we use the three alternative estimators, i.e. the MG, the PMG and the DFE, for the ECM panel data regression in terms of (14) for China's 28 provinces during the reform period 1978-1997. Table 3 presents estimates of the long-run coefficients, the adjustment coefficient, LR statistics and joint Hausman Test statistics. The comparison among the MG, the PMG and the DFE estimators is based on both the LR test and Hausman test. All regressions include a time trend.

The MG imposes no homogeneity and the standard error of the MG estimate is calculated in exactly the same way as the standard error of the mean while the standard deviation of the individual coefficients divided by the square root of N (see Pesaran, Smith and Im, 1999). Because the time span of our panel data is only 20 years, the MG estimator suffers from the shortage of degrees of freedom and the estimated standard error for individual convergence regression is too large. As we can see from Column 4 of Table 3, the long-run estimates of β_i and γ_i are not significant. Hence the MG estimator is not useful for our empirical purpose.

We focus on two estimates of the PMG estimator with different long-run coefficient restrictions. The first PMG (PMG1) estimates are obtained by imposing equality of both β_i and γ_i. The second PMG (PMG2) estimates are obtained by imposing equality only on the capital coefficient β_i and allow the trade coefficient γ_i to differ across the provinces. The Hausman test is used to test the long-run homogeneity restrictions of two PMG estimates against the MG estimates and the p-values are 0.75 and 0.80, respectively. The joint Hausman results mean that we can not reject the restrictions for the PMG1, i.e. the long-run coefficients β_i and γ_i are homogeneous across all provinces, and the restrictions for the PMG2, i.e. only the long-run coefficient β_i are homogeneous across all provinces, respectively. We use the LR test to distinguish the two nested PMG estimates. In particular, the long-run homogeneity restriction on the trade coefficients γ_i of the PMG1 estimate against the no long-run restriction on γ_i of the PMG2 estimate is rejected by the LR test at the 1% confidence level.

Finally we look at the DFE estimator, which imposes equality on all slope coefficients and only allows the intercepts and error variances to differ across the provinces. According to the LR test, the homogeneity of DFE estimator imposing on the PMG1 is rejected at 1% confidence. It implies that the DFE suffers from the heterogeneity problem.

Therefore, the PMG2 estimate, only with the restrictions on the capital coefficient β_i, is significantly preferred among the MG, DFE and the PMG1 estimate. The PMG2 estimate reports that the long-run capital coefficient is 0.288 and significant. The average adjustment coefficient is significantly negative and is -1.059 (<-1). This implies that the average adjustment speed is relatively high and provincial income overshoots its target income level repeatedly. Thus, this means that the ECM model accommodates a business cycle effect in the data. More importantly, the PMG2 estimate allows the long-run trade spillover coefficients γ_i to differ across the provinces. While the average long-run coefficient is positive with value 0.119 and is not significant, the estimated γ_i for individual provinces is very interesting. Table 4 reports the individual long-run spillover effects of trade on economic growth. It shows that 15 out of 28 provinces' long-run trade knowledge spillover effects are significantly positive.

This implies that the positive effects of trade-knowledge spillover cause these 15 provinces to exhibit increasing returns to scale. But one province (Heilongjiang) has a significantly negative effect. Furthermore, the individual estimates show that there are substantial differences among the provinces in terms of long-run trade knowledge spillover effects.

The rest of the 12 provinces' estimates of trade spillover effects are not significantly different from zero. This result is different from our expectation according to the finding of a long-run relationship among per capita income, capital stock and trade. The main reason is that the estimation procedure of the PMG estimator is pooling individual ECM time series estimation together and then imposing some long-run homogeneity restrictions such as a common capital coefficient β_i across the provinces. Because the time series span in the panel is only 20 years, the PMG estimates may still suffer from the shortage of degrees of freedom and the estimated standard error for individual ECM regression may be too large. In addition, the single homogeneity restriction on β_i can not sufficiently increase the degree of freedom. Hence, the long-run trade coefficient estimates of the 12 provinces are insignificant. To prove this point, the additional homogeneity restrictions on γ_i in the first PMG estimate helps to increase the degree of freedom so that the estimated γ becomes highly significant with a positive value of 0.032, while this additional restriction is rejected by the LR test.

Finally, the five dragons' knowledge spillover coefficients are 0.329, 0.325, 0.264, 0.220 and 0.204 for Jiangsu, Zhejiang, Fujian, Shandong and Guangdong, respectively[11] and higher than the average coefficient 0.119 of all provinces. The reason for these high positive coefficients may be due to the five dragons'

[11] The coefficient of Zhejiang is not significant.

outstanding familiarities to the foreign knowledge, which may benefit from the nearby Chinese-speaking economies of Hong Kong, Taiwan and Singapore[12]. However, Heilongjiang, a north-east province near the former Soviet Union, suffers from a significantly negative impact of knowledge spillover effect ($\gamma = -0.111$). Heilongjiang has more involvement with the former Soviet Union and represents the best example of the Soviet-style industrialization during the pre-reform period. Consequently, its familiarity with its main trading partners, i.e. the OECD countries and East Asian economies, is very low during the reform period and thus may be responsible for the negative spillover effect.

5.4 Provincial Growth Accounting with Spillover Effects

TFP measured by the "Solow residual" in the normal growth accounting may be no more than a measure of our ignorance (Temple, 1999). By contrast, the production function with knowledge spillover such as equation (12) allows for a sharper perspective on the Solow residual (Barro, 1999). Within this setting, TFP can be further interpreted in terms of measures of the trade knowledge spillover effect.

The growth accounting can be obtained according to the long-run production function (12) as follows

$$g_i = \beta_i \Delta k_{it} + \Delta TFP = \beta_i \Delta k_{it} + \underbrace{\gamma_i \Delta R_{it} + \Delta e_{it}}_{\Delta TFP} \tag{18}$$

where g_i, Δk_{it} and ΔR_{it} are the average annual growth rates of GDP, capital stock and international trade per capita for the province i over the reform period 1978-97. $\Delta TFP = \gamma_i \Delta R_{it} + \Delta e_{it}$, $\gamma_i \Delta R_{it}$ is the contribution of trade spillover

[12] Fujian is in front of Taiwan and Guangdong is in front of Hongkong. Also, these five provinces have close link with overseas Chinese.

effects.

A natural benchmark for this provincial growth accounting is the post-war growth of the Newly Industrializing Countries of East Asia, i.e. Hong Kong, Singapore, South Korea and Taiwan, which has profoundly influenced economists' evaluation of the potential gains from trade liberalization processes. The extraordinary rapid and sustained nature of growth in these economies, along with its apparent association with the growth of international trade, has led many economists to argue that there are enormous TFP dynamic gains from trade liberalization (e.g. Baldwin, 1992). However, recent research by Young (1995) has generated considerable controversy by suggesting that productivity growth may have accounted for only a small fraction of the growth of these East Asian economies, with capital accumulation being responsible for the bulk of it. Some figures may be helpful. In Hong Kong, GDP per capita grew by 5.7% per year during 1966-92. During 1966-90, Singapore's GDP per capita grew at 6.8% per year, South Korea's also at 6.8% per year, and Taiwan's at 6.7%. Young (1995) uses the aggregate production function approach to separate out the contribution to this growth of factor accumulation and TFP growth. He derives estimates of the contribution made by TFP growth (the Solow residual). For the same time periods as before, he finds that TFP growth rates were 2.3% a year for Hong Kong, 0.2% for Singapore, 1.7% for South Korea, and 2.1% for Taiwan. Young argues that these figures are not exceptional by the standards of the OECD or several large developing countries. It seems to imply that TFP is relatively unimportant as the source of the "East Asia Miracle".

By contrast, it seems that the case of China's provinces is consistent with the dynamic gain from trade knowledge spillover effect. Table 5 shows that all provinces' TFP growth except Beijing[13] is much greater than capital accumulation growth. This provincial breakdown echoes the findings of the previous growth accounting studies at the national level (Borensztein and Ostry, 1996; Hu and Khan, 1997), which show that capital accumulation has retreated to a secondary role and TFP has become the primary drive force of China's economic growth after 1978.

Besides TFP gain, capital accumulation is another channel through which the trade can affect economic growth as discussed in Chapter 7. Baldwin (1992) suggests that the advanced knowledge embodied in the South-North trade raises the return to capital of the South and it will induce capital formation and therefore raise income of the South. In our context, this trade-growth mechanism would predict that the growth accounting would find that the economy that experienced greater capital accumulation also experienced greater TFP growth. Figure 1 shows that higher TFP growth rates are correlated with higher capital growth rates, and vice versa. This finding is consistent with prediction that trade increases the returns to capital accumulation and thus induces a higher investment rate.

While the spillover effect is an important source of TFP growth in the fifteen provinces, the contribution of the spillover effect to TFP varies largely across the provinces. The five dragons (Guangdong, Fujian, Jiangsu, Shandong, Zhejiang) have enjoyed substantial and dynamic gain from international trade spillover. However, Heilongjiang's TFP growth has been significantly offset by the negative contribution of the trade spillover effect. Trade spillover effects on TFP growth help to explain why the five dragons are flying but Heilongjiang is

[13] A possible explanation for Beijing is that Beijing, as the capital of China, can access to more investment sources such as the state investment.

falling behind.

6 Concluding Remarks

The major methodological contribution of this chapter is the introduction of a trade-induced catch-up model. In particular, the basic setting of the model is that the South-North trade causes a trade-embodied knowledge spillover to the South, which intensifies market competition pressure for the firms in the South and meanwhile provides them with an opportunity to imitate the more advanced technology of the North. Nickell's solution to this intertemporal cost minimisation problem is a catch-up dynamics in a ECM form which has enjoyed popularity in the applied economics (Domowitz and Kakkio, 1990). The target labour productivity is determined by the production function with trade-embodied spillover effects. Its econometric implementation is done by the PMG estimator of panel data.

This model is applied to Chinese provincial data during the reform period 1978-1997. The main empirical findings are:

(1) The underlying economic growth mechanism for China's remarkable growth at the province level can be described by the trade-induced catch-up process towards their trading partners especially the OECD countries and East Asian economies. Imitation benefit has enabled the provincial economies to approach their own long-run income targets, which are endogenously determined by the production function with trade-embodied knowledge spillover effects.

(2) We have identified 15 provinces enjoying positive trade-embodied knowledge spillover effects and 1 province (Heilongjiang) suffering from a negative spillover effect. Unfortunately, we are not able to pin down the long-run spillover

effects of the remaining 12 provinces, mainly due to data limitation. Nevertheless, we believe that spillover effects have a generally positive long-run impact on the economic growth of China, and these findings can explain China's remarkable growth performance during the reform period 1978-97.

(3) The different knowledge spillover effects of individual provinces are mainly responsible for the different economic growth performance. A possible reason for the different spillover effects is the province-specific familiarity with the trade-embodied knowledge stock. For some provinces especially the five dragons, the familiarity is high but for others such as Heilongjiang's familiarity may be very low.

(4) The growth accounting analysis provides an explanation for the different growth performance of China's provinces after 1978. In particular, it demonstrates that the TFP growth is more important than capital growth in all provincial economies except Beijing. Thus, we confirm the results of the previous growth accounting studies for Chinese national economy (Borensztein and Ostry, 1996; Hu and Khan, 1997). In addition, we find that the knowledge spillover effect is a very significant component of the TFP growth. In the case of the five dragons, the contribution of trade spillover effect is prominent. Heilongjiang is significantly damaged by the negative trade knowledge spillover effect. Overall, the knowledge spillover benefits vary across the individual provinces and thus causes significant differences of long-run growth rates among the provinces.

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Tables and figures

Table 1: Average Annual Growth Rates of Per Capita GDP of China's 28 Provinces during the reform period 1978-97

Province	Growth Rate of Per Capita GDP
Anhui	9.22
Beijing	7.91
Fujian	12.64
Gansu	7.62
Guangdong	11.51
Guangxi	8.23
Guizhou	8.22
Hebei	9.47
Heilongjiang	6.70
Henan	9.70
Hubei	9.64
Hunan	8.21
Inner Mongolia	8.57
Jiangsu	12.33
Jiangxi	9.36
Jilin	8.93
Liaoning	7.88
Ningxia	7.21
Qinghai	5.88
Shaanxi	8.37
Shanghai	8.35
Shandong	10.83
Shanxi	8.16
Sichuan	9.68
Tianjin	8.53
Yunnan	8.99
Xinjiang	8.99
Zhejiang	13.27
Average	9.09

Table 2: IPS Tests for Panel Unit Roots

	Intercept, no trend t-bar test
y_{it}	2.25
k_{it}	8.41
R_{it}	2.54
Δy_{it}	-6.23
Δk_{it}	-3.42
ΔR_{it}	-3.24

Notes: Two tests are one-sided. The relevant critical values for the t-bar test are obtained from the lower tails of the standard normal,i.e. -1.28 (10%) -1.645 (5%) and -2.33 (1%) respectively. The top-down approach has been used to select the lag orders for each time sereis (Campbell and Perron, 1991)

Table 3: Alternative Estimates of the Error-Correction Catch-up Model for China's Provinces over 1978-97

Long-run Coefficients	1 DFE	2 PMG1	3 PMG2	4 MG
β_i	0.256$^+$	0.295$^+$	0.288$^+$	0.048$^\wedge$
	(0.025)	(0.018)	(0.042)	(0.453)
γ_i	0.160$^+$	0.032$^+$	0.119$^\wedge$	0.077$^\wedge$
	(0.022)	(0.006)	(0.091)	(0.062)
Adjustment Coefficients ω	-0.480$^+$	-0.780$^\wedge$	-1.059$^\wedge$	-0.785$^\wedge$
	(0.015)	(0.091)	(0.116)	(0.172)
Hausman Test		p=0.75	p=0.80	
LR Test p-value	0.000	0.001		

Note: The figures in brackets of the PMG and MG estimators are standard errors. The figures in DFE estimator's brackets are White robust standard errors. Mean group estimates are used as initial values. Orders of Lags in the ARDL model which are selected by AIC. The maximum of lags is 3. Newton-Raphson algorithm is used. + means parameters are resrtricted to be the same and ˆ means the average coefficient across provinces. Time trend is included in all regressions.

Table 4: The Long-run Trade-embodied Knowledge Spillover Coefficients for Each Province of China

Province	γ_i
Anhui	-0.149 (0.188)
Beijing	0.029* (0.007)
Fujian	0.264* (0.065)
Gansu	-0.084 (0.067)
Guangdong	0.204* (0.017)
Guangxi	0.827 (0.747)
Guizhou	-0.052 (0.053)
Hebei	0.101* (0.020)
Heilongjiang	-0.111* (0.015)
Henan	0.048* (0.020)
Hubei	-0.041 (0.010)
Hunan	-1.150 (2.224)
Inner Mongolia	-0.030 (0.095)
Jiangsu	0.329* (0.051)
Jiangxi	-0.086 (0.054)
Jilin	0.039* (0.015)
Liaoning	0.218* (0.057)
Ningxia	-0.121 (0.091)
Qinghai	0.127* (0.023)
Shaanxi	0.030* (0.005)
Shandong	0.220* (0.0293)
Shanghai	2.022 (3.406)
Shanxi	0.053* (0.010)
Sichuan	0.017 (0.016)
Tianjin	0.152* (0.029)
Xinjiang	0.084* (0.015)
Yunnan	0.067* (0.025)
Zhejiang	0.325 (0.209)
Average	*0.119 (0.091)*

*Note. The figures in brackets are standard errors. * means the coefficient is significant at 5% confidence level.*

Table 5: Growth Accounting with Trade Knowledge Spillover for China's Provinces 1979-1997

Province	gGDP	gk	gTFP	gR
Anhui	0.0904	0.0238	0.0665	N/A
Beijing	0.0736	0.0390	0.0347	0.0074
Fujian	0.1146	0.0289	0.0857	0.0767
Gansu	0.0690	0.0139	0.0551	N/A
Guangdong	0.1122	0.0414	0.0708	0.0574
Guangxi	0.0773	0.0122	0.0651	N/A
Guizhou	0.0706	0.0145	0.0561	N/A
Hebei	0.0867	0.0257	0.0610	0.0191
Heilongjiang	0.0623	0.0239	0.0384	-0.0330
Henan	0.0903	0.0250	0.0653	0.0087
Hubei	0.0888	0.0221	0.0666	N/A
Hunan	0.0742	0.0201	0.0541	N/A
Inner Mongolia	0.0815	0.0267	0.0548	N/A
Jiangsu	0.1087	0.0419	0.0668	0.0590
Jiangxi	0.0864	0.0243	0.0621	N/A
Jilin	0.0822	0.0243	0.0579	0.0108
Liaoning	0.0735	0.0189	0.0546	0.0378
Ningxia	0.0679	0.0122	0.0557	N/A
Qinghai	0.0514	0.0152	0.0362	0.0241
Shaanxi	0.0777	0.0204	0.0573	0.0094
Shanghai	0.0754	0.0288	0.0466	N/A
Shandong	0.1012	0.0310	0.0707	0.0485
Shanxi	0.0723	0.0215	0.0508	0.0190
Sichuan	0.0812	0.0189	0.0623	N/A
Tianjing	0.0747	0.0244	0.0503	0.0269
Xinjiang	0.0851	0.0281	0.0570	0.0217
Yunnan	0.0793	0.0138	0.0656	0.0146
Zhejiang	0.1189	0.0360	0.0829	0.0718
Average	*0.0831*	*0.0242*	*00590*	*0.0282*

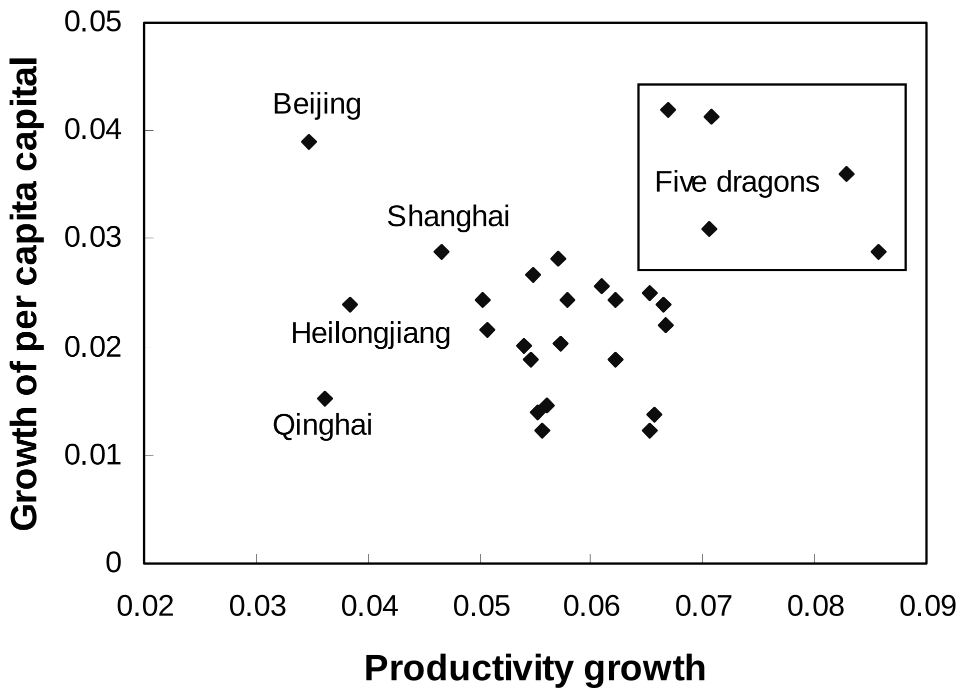

Figure 1: Partial Association between Annual Average of Productivity (TFP) Growth and Per Capita Capital Stock Growth of China's Provinces 1979-1997