Testing Effects of Openness in the process of China's Economic Growth During 1978-1995

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Abstract

This paper presents an endogenous growth model in which the growth rate of income is higher if the economy is more open. Openness, measured by the ratios of imports and of foreign direct investment to GDP, is hypothesised to affect economic growth through its impact on technological changes. The hypothesis cannot be rejected with Chinese data at the provincial level for the period 1978-1995 as there is a significantly positive correlation between growth of real GDP per worker and the measures of openness. This paper further tests the robustness of the effect and studies the alternative effects of openness on economic growth.

1 Introduction

The long-run relationship between economic growth and openness to trade has been established in the models of endogenous growth. Openness to trade is supposed to *i*) provide access to imported inputs, which embody new technology; *ii*) increase the effective size of the market facing producers, which raises the returns to innovation; and *iii*) affect a country's specialisation in research-intensive production. Motivated by the endogenous growth models, recent empirical studies[1] use cross-country data to test the correlation between openness and economic growth. Despite the already voluminous empirical efforts in this area, debates still exist over the channel through which openness to trade affects growth.

This study attempts to test the relation between growth and openness with Chinese data at the provincial level during the period 1978-1995. It hypothesises that openness affected China's economic growth during 1978-1995 through its impact on technological progress. The

[1] The list is not exhausted by Edwards (1992 and 1998), Blomstrom, Lipsey and Zejan (1994), Borensztein, Gregorio and Lee (1995), Lee (1995) and Harrison (1996).

theoretical framework underpinning the test of the hypothesised effect of openness is a model of endogenous growth in which technological progress is the main determinant of the long-run growth rate of income. Here technological progress takes place through a process of capital deepening in the form of the introduction of new varieties of intermediate inputs.

A small extension of the model by the study is the involvement of openness into the model according to the idea that introduction of new varieties of intermediate inputs depends on the imitation of foreign technology as well as domestic innovation for a developing country like China. Openness provides access to imported inputs which embody advanced technology, and foreign investment which brings in disembodied new technology. The more open an economy, the quicker the process of the introduction of new varieties of intermediate inputs.

Empirically, in this country-specific study, openness is measured by trade intensity as trade regime is the same across provinces. We will firstly test the hypothesised effect of openness on China's economic growth during 1978-1995 through its impact on technological progress in the regression controlling for domestic inputs of production. The measure of openness by trade intensity is compatible across provinces, but it may be endogenous. To overcome the potential endogeneity of openness, reversed causality from growth to openness and simultaneity between growth and openness, we will use the two-stage least squares model additionally in the estimation.

Secondly, it is of interest to see whether the adoption of foreign technology by the Chinese provincial economies depends on their endowment of human capital. To this end, we will examine the interaction terms between the measures of openness and the secondary school enrolment rates. Finally, we will estimate the correlation between the measures of openness and the ratio of total investment to GDP to investigate whether openness affects growth through enhancing capital accumulation.

The rest of the study is organised as follows. In section 2, the theoretical framework is presented. Section 3 specifies the empirical model and discusses the methodology of estimation. The basic estimation results are interpreted and discussed in section 4. Section 5 reports the results from the alternative specifications. Section 6 concludes. Data description is presented in appendix.

2 The Theoretical Framework

In this section, we present the framework of endogenous growth generated by technological progress. Technological progress takes place through a process of capital deepening in the form of the introduction of new varieties of intermediate inputs subject to domestic (local) innovations and diffusion of technology.

This section first considers the situation that firms are open to each other within provinces and close to the outside world. Technological progress is represented by an expansion of the number of the varieties of inputs under the domestic (local) innovation and spillovers of knowledge at the provincial level. And then the model is extended to an open economy where the rate of technological progress is influenced by foreign inputs through trading and investment. The involvement of foreign trade produces within-firm learning which benefits directly the technological progress of the firms pursuing imports while inward foreign direct investment enhances the spillovers of knowledge across local firms.

The theoretical framework is closely related to Romer (1990) and Grossman and Helpman (1991) which provide the endogenous property of the model, and partially motivated by Edwards (1992), which suggests two different sources of technological progress for a developing country. The primary aim of this theoretical presentation is to derive an estimating equation rather than illustrate a new economic mechanism, or explore the boundaries of existing models. In presenting the model, we draw exclusively on Barro and Sala-i-Martin (1995, Chapter 6).

2.1 The Model of Endogenous Growth with an Expanding Variety of Products: In the closed situation

In this subsection, we assume that firms are open to each other within provinces but close to the outside world, including other provinces. Firms in a province produce a single good for the uses of consumption and innovation and production of new goods as in the one-sector neo-classical production model. Suppose that firms takes the following Cobb-Douglas technology of production:

$$Y_i = A_i L_i^{1-\alpha} K_i^{\alpha}, \ 0<\alpha<1,$$

where α is fixed capital share, Y_i is the output of firm *i*, A_i represents the level of the technology of firm *i*, L_i denotes labour input and K_i stands for physical capital of firm *i*. Here, we do not include human capital as a separate input of production, but regard it as a prerequisite for the adoption of foreign technologies in the following section.

Following Barro and Sala-i-Martin (1995), in this model, we assume that physical capital consists of an aggregate of different varieties of intermediates[2],

$$K_i = [\sum_{k=1}^{N} (X_{ik})^{\alpha}]^{1/\alpha}$$

where X_{ik} is the *k*th type of intermediate good employed by firm *i* and *N* is the number of varieties of intermediates available. Suppose that all the varieties of intermediates are employed in the same quantity, $X_{ik}=X_i$,, the quantity of output is then given by

[2] Barro and Sala-i-Martin (1995) justify that they could get essentially the same results if an integral over a continuum of types (Ethier, 1982), $K = \{\int_0^N [X_i(k)]^{\alpha} dk\}^{1/\alpha}$, instead of the sum over a discrete number of types, is used.

$$Y_i = A_i L_i^{1-\alpha} N X_i^{\alpha} = A_i L_i^{1-\alpha} (N X_i)^{\alpha} N^{1-\alpha} \tag{1}$$

where NX_i is the total quantity of intermediates of firm i. For given N, equation (1) implies that production exhibits constant returns to scale in L_i and NX_i. Holding L_i and N constant, equation (1) indicates that an increase in X_i encounters diminishing returns. However, marginal product with respect to N is a constant. Diminishing returns do not arise if the increase in NX_i takes the form of a rise in N for given X_i. Thus, technological progress in the form of expanding varieties of intermediates avoids the tendency for diminishing returns. The absence of diminishing returns provides the source for endogenous growth.

We assume that specialised firms produce each variety of intermediate good, and rent it out to final goods producers at rental rate R_k. This rental rate is equal to the marginal productivity of the intermediate in the production of the final good, that is

$$\partial Y_i / \partial X_{ik} = A_i \alpha \cdot L_i^{1-\alpha} \cdot X_{ik}^{\alpha-1}$$

The equality between the marginal product and R_k therefore implies the demand for each variety of intermediates by firm i, X_{ik}, as

$$X_{ik} = L_i \cdot (A_i \alpha / R_k)^{1/(1-\alpha)}$$

The provincial economy's demand for kth type of intermediate will be

$$X_k = \sum_i X_{ik} = (A\alpha / R_k)^{1/(1-\alpha)} \cdot \sum_i L_i = L \cdot (A\alpha / R_k)^{1/(1-\alpha)} \tag{2}$$

where A is the technology at the provincial level and L is the total labour input of the province. We assume that the spillovers of knowledge operate at the level of the provincial economy so that A_i, the level of the technology for firm *i,* tends to converge to the technology at the provincial level, A, in the long run. This assumption captures the influence of technological progress across firms within provinces. The point is that each firm's knowledge is a public good that any other firm within the province can access at zero cost. In other words, once discovered, a piece of knowledge spills over across firms gradually although firms have incentives to maintain secrecy over their discoveries and there is formal patent protection for inventions.

We also assume that the provincial labour input, L, is a given endowment in the study of long-term growth in consistence with the neo-classical assumption. According to the assumption, exogenous population growth is a long-run determinant of labour input. Because the long-run growth seems to require explanation in terms of stock variables and population, as a proxy for the labour force, is such a variable. For a country-specific study, labour is supposed to move freely between regions and the labour movement should be taken into consideration. However, labour movement between provinces was restricted in China during the period under study. And the most of labour migration was observed within provinces from the agricultural sector to industrial production. Thus it is reasonable to omit the labour movement across provinces in the case of China during 1978-1995.

At a point in time, the technology exists to produce N varieties of intermediate goods. An expansion of the number N requires technological advance in the sense of an invention or adaptation that permits the production of the new kind of intermediate goods. To simplify the analysis, we assume that it needs a deterministic amount of effort to generate a successful new intermediate. The cost to create a new type of product is assumed to be fixed at η units of Y_i, as we have assumed that R&D is one of the uses of the flow of current output. In other words, we assume that the marginal cost of producing an intermediate is constant at 1. To provide incentives to invent, the inventor of kth type of intermediate good should be awarded a perpetual monopoly right over the production and sale of the good that uses his design. The monopolist sets the price of intermediate good (R_k) to maximise the flow of monopoly profit, $(R_k-1)X_k$, at each date.

Substituting the above X_k in equation (2) into the expression of the monopoly profit, $(R_k\text{-}1)X_k$, we have

$$(R_k - 1) \cdot L \cdot (A\alpha / R_k)^{1/(1-\alpha)}$$

Differentiating the above expression of monopoly profit with respect to R_k and equating it to 0, we have the solution for the monopoly price: $R_k=1/\alpha$, which is the mark-up on the marginal cost of production, 1. We assume that the newly produced intermediate is not direct substitute for or complement with those already existing so that these monopoly prices can be maintained. The present value of the returns from discovering the kth intermediate good is then:

$$V_k = \int_t^{\infty} (R_k - 1) \cdot X_k \cdot e^{-r(v-t)} dv\,, \tag{3}$$

where r is a constant average interest rate between times t and v, and $e^{-r(v-t)}$ is the present-value factor. When there is free entry into the business of innovation, anyone can capture the net present value, V_k, by paying R&D cost η, i.e. $V_k=\eta$. Hence, the interest rate will be such that profits are equal to zero. Solving for the zero profits condition we obtain the interest rate by substituting R_k and X_k to equation (3):

$$r = \tfrac{L}{\eta} \cdot A^{1/(1-\alpha)} \cdot \tfrac{1-\alpha}{\alpha} \cdot \alpha^{2/(1-\alpha)} \tag{4}$$

Since we assume that a new type of product is neither a direct substitute for nor a direct complement with the types that already exist, old and new products receive the same flow of monopoly profits. The present value of the profits for each existing and just about to be discovered intermediate must equal to η. Thus η is the market value of a firm that possesses the blueprint to produce one of the intermediates, and the aggregate market value of the provincial economy is ηN.

To close the model, we need to describe the process of capital accumulation, which is driven by households' saving behaviour. Households earn the wage rate on labour and the rate of return on assets. In this closed economy, the total of households' assets equals the market value of the economy, ηN. Savings equal investment, ηdN, which, in turn, equals the resources expended on R&D. dN is the change in N. We assume that households maximise utility over an infinite horizon:

$$U = \int_0^{\infty} e^{-\rho t} \cdot \frac{c_t^{1-\theta} - 1}{1-\theta} \, dt, \tag{5}$$

where c denotes quantity of per capita consumption of the final goods, and ρ and θ are household's preference parameters, i.e. willingness to substitute its consumption intertemporally, which relate to saving behaviour. The key condition from households' optimisation is the expression for the growth rate of per capita consumption:

$$\gamma_c = \frac{1}{\theta}(r - \rho), \tag{6}$$

γ represents a growth rate of the variable denoted by the subscript letter. Substituting the expressions of r from equation (4) into equation (6), we have:

$$\gamma_c = \frac{1}{\theta}\left\{\frac{1}{\eta} \cdot L \cdot A^{1/(1-\alpha)} \cdot \frac{1-\alpha}{\alpha} \cdot \alpha^{2/(1-\alpha)} - \rho\right\} \tag{7}$$

In the steady state, the growth rate of per capita consumption applies to the growth rate of per capita output. Equation (7) is the growth equation for the provincial economies in the closed situation. The growth rate is a positive function of the level of the production technology, A, and the scale effect, L and a negative function of the households' preference parameters, ρ and θ, and the cost of inventing a new product, η.

The scale effect says that the larger the economy, represented by L, the lower the cost of an invention per unit of L or Y . A new product, which costs η, can be used in a non-rival manner across economy and the cost of carrying out R&D per unit of economic activity is effectively η/L. An increase in L therefore has the same effect on the growth rate in equation (7) as a decrease in η.

2.2 The model in the open situation

Once the economy opens up to the outside world, the one-sector economy produces the single goods for final consumption, innovation and production of intermediates, and exports in exchange for the foreign goods. In order to keep trade in balance, we assume that the economy exports its final goods in exchange of the imports of foreign intermediates. The intermediate input can be produced domestically and imported from the advanced nations. The number of imported intermediate varieties is denoted by N_f. We emphasise the imperfect substitutability between the domestically-produced and imported intermediate goods so that, firstly, the economy will not specialise in using relatively advanced foreign intermediates at cheaper prices and secondly, the domestic inventors can still have a monopoly right over their innovations.

In this open situation, technological progress is still expressed by an increase in the number of varieties of intermediates and dependent upon the domestic innovation. The domestic innovation, however, is obviously influenced by foreign technology from advanced countries through foreign trade and investment.

Foreign direct investment by multinational corporations (MNCs) is often suggested as a vehicle for the international diffusion of technology. MNCs have undertaken a major part of the world's research and development efforts, and today they control most of the world's advanced technologies. The developing countries like China, with limited resources for R&D, are particularly dependent on foreign multinationals for access to modern technology.

Simply by setting up operations that are beyond the technological capabilities of the host country's firms, foreign direct investment may bring in disembodied technology. If the foreign affiliates' technology leaks out to local firms (spillover of technology), foreign direct investment may also result in indirect productivity gains for host countries.

On the other hand, under the assumption of within-firm learning, imports of relatively advanced foreign intermediate goods facilitates the imitation of technology, which will reduce the cost of innovating and producing a new product. In the other words, the cost of inventing a new intermediate is lower if the economy imports more relatively advanced intermediates. The idea behind it is that imitation is cheaper than innovation.

The above two channels of the diffusion of foreign technology are in consistence with the Lewis (1957) argument that developing countries that are more integrated to the rest of the world will have an advantage in absorbing technological innovations generated in the advanced nations. In this context more integrated should be interpreted as referring to a larger share of foreign trade in GDP, a less distorted foreign trade sector and a heavier involvement of foreign direct investment. In addition, there is a catch-up effect, which states that the wider the gap between domestic and foreign technologies, the faster the integration will promote the economy's technological progress.

Based on the above considerations, we assume that the cost of innovation is negatively affected by openness and the gap between domestic and foreign knowledge. Openness can be measured by the ratio of the imported intermediates to the total employment of the intermediates, $N_f X_i / N X_i$. Since we assumed that all the varieties of intermediates are employed in the same quantity, the ratio of the imported intermediates to the total employment of the intermediates becomes N_f/N. The gap between domestic and foreign knowledge is denoted by the expression, $(N^*-N)/N$, where N^* is the total number of varieties of intermediates available in the world while N is the number of varieties available for the economy including domestically-produced and imported ones. So the profits for domestic innovation become:

$$\Pi_j = \int_t^{\infty} (R_j - 1) \cdot X_j \cdot e^{-r(v-t)} dv - \eta(1 - \frac{N_f}{N} - \frac{N^* - N}{N})$$

Suppose that there is free entry, and hence, the rate of return r will be such that profits are equal to 0. Solving for the zero profits conditions we obtain:

$$r = \frac{L}{\eta(1 - \frac{N_f}{N} - \frac{N^* - N}{N})} \cdot A^{1/(1-\alpha)} \cdot (\frac{1-\alpha}{\alpha}) \cdot \alpha^{2/(1-\alpha)} \qquad (4)'$$

We assume, as usual, that households maximise utility over an infinite horizon as equation (5). The key condition from households' optimisation is the expression for the growth rate of per capita consumption as equation (6). Substituting the expression for the interest rate from equation (4)' into equation (6), we have:

$$\gamma_c = \frac{1}{\theta} \{ \frac{L}{\eta(1 - \frac{N_f}{N} - \frac{N^* - N}{N})} \cdot A^{1/(1-\alpha)} \cdot \frac{1-\alpha}{\alpha} \cdot \alpha^{2/(1-\alpha)} - \rho \} \qquad (7)'$$

In the steady state, the above growth rate of per capita consumption will apply to the growth rate of per capita output as in the previous section. The rate of economic growth is determined additionally by the ratio of the imported intermediates to the total employment of intermediates and the technological gap between domestic economy and foreign nations. The higher the ratio of imported ones to total employment of intermediates and the larger technological gap between domestic and world economies, the lower the cost of inventing a new product. Lower cost will bring about higher rate of economic growth in this model.

3 Specification of the empirical model

In the previous section, we derived a growth equation (7') for the Chinese provincial economies in the open situation, and more importantly, we hypothesised the positive effects of openness on economic growth through technological progress. In order to facilitate empirical estimation, in this study we mainly focus on a linear relationship between growth and its determinants. Taking natural logarithm of both sides of equation (7'), the basic regression equation for estimation is the following:

$$\ln GRO=\alpha+\beta\ln GAP+\delta\ln OPEN+\sum\phi_i\ln RELEV_i+\mu \quad (9)$$

where GRO[3] is growth rate in real GDP per worker, GAP is the technological gap between domestic and world economies, OPEN is a measure of openness of an economy, RELEV is a set of other variables (i=1, 2 and 3) relevant to economic growth, and μ is an error term. The slope coefficients on explanatory variables, β, δ and ϕ, measure respectively the partial elasticity of economic growth with respect to the explanatory variables, that is, the percentage changes in economic growth in response to a percentage change in the explanatory variables given other variables. Equation (9) will be adjusted according to the approach used in the subsequent estimation. From the regression model, we will test the effects of openness on economic growth and quantify the contributions of determinants of China's economic growth.

Our data on the above variables cover 18 years (1978-1995) across 29 out of 30 provinces in China. Tibet is dropped due to the unavailability of data on foreign direct investment. Variable of interest, openness, is measured by the ratios of imports and of foreign direct investment to GDP. Trade policy or regime, which is widely used as the measure of openness in the comparison across countries, is the same across provinces within the nation. In this country-specific study, it is reasonable to define openness simply as an economy's, a province in this case, trade intensity (the magnitude of traded output relative to all output), import penetration and utilisation of foreign direct investment.

[3] All the variables to be used are described in the appendix.

We apply three econometric approaches to the empirical study from three different angles. Firstly, the single cross-sectional approach uses averages of variables over time and considers one cross-section across groups. The cross-province comparison of average growth rates over a substantial time span, 18 years in our case, is appropriate to investigate the long-run effects. Specifically we will regress natural logarithm of growth rates in real GDP per capita, $(\ln Y_{j,1995}-\ln Y_{j,1978})/17$, on natural logarithm of the regressors included in equation (9). All regressors, except *GAP*, are also averaged over time. Thus equation (9) will look like

$$lnGRO_j=\alpha+\beta lnGAP_j+\delta lnOPEN_j+\sum\phi_i lnRELEV_{ij}+\mu_j \qquad j=1,2,...,29 \qquad (9\text{-}1)$$

where *i* is the index for the variables in the vector of RELEV.

However, the single cross-section approach considers only one cross-section which forces the use of some rather restrictive assumptions in the econometric specification. The measures of openness can be influenced by each province's structural characteristics, such as natural resources, natural trade barriers and family ties with overseas Chinese. These variables reflecting individuality of provinces sometimes are difficult to measure or hard to obtain so that not all the variables are available for inclusion as regressors in the regression equations of the cross-section study. Although these variables are included in the error term, the unmeasurable variables are assumed independent from the explanatory variables included in the regression by OLS. This amounts to ignoring province-specific effects thus it will yield biased and inconsistent estimates. Consequently, the parameter estimates may display spurious correlation. We would be misled into accepting or rejecting the hypotheses.

In order to correct bias of the omitted variables, secondly, we use a panel data analysis. The basic regression equation used in the analysis is

$$lnGRO_{jt}=\alpha+\beta lnGAP_{jt}+\delta lnOPEN_{jt}+\sum\phi_i lnRELEV_{ijt}+\mu_{jt} \qquad j=1,..., 29;\ t=1, 2, 3. \qquad (9\text{-}2)$$

The model may be treated as either fixed or random effect. The fixed-effect model estimates each intercept term for individuals, i.e. provinces in our case, which is constant over time. The varied estimates of intercept terms across provinces capture the unmeasurable province-specific effects. The random effect model, instead, estimates an intercept term constant across individuals and over time and views the individual-specific intercept terms as randomly distributed across cross-sectional units. Since we are focusing on a specific set of provinces in China and our inference is restricted to the behaviour of this set of provinces, the fixed effects model is supposed to be an appropriate specification. Moreover, the random effect model assumes that province-specific effects are uncorrelated with the independent variables included, and hence it may be subject to omitted variable bias and inconsistency.

However, this view is disputed by Mundlak (1978), who argued that we should always treat the individual effects as random and that the fixed effects model is analysed conditionally on the effects presented in the sample. Practically, the random effect model is more efficient, because the fixed-effect model which uses dummy variables is costly in terms of valuable degrees of freedom.

In this study we use data to provide the guidance on the choice between the fixed-effect and random effect models. Under the null hypothesis of no correlation between the province-specific effects and the explanatory variables involved, both the fixed and random effect models are consistent, but the former is less efficient. Under the alternative, the fixed effect model is consistent whereas the random effect is not. The validity of these two models can be determined by using a Hausman test, which is based on the difference between the parameter and variance estimates. When the observed value of the Hausman test is larger than the critical value of χ^2-distribution under a specific degrees of freedom, we can reject the null hypothesis that there is no correlation between the province-specific effects and the included independent variables. It is evidence in favour of the fixed-effect model. When the observed value of Hausman test is less than that of χ^2-distribution under a specific degrees of freedom, we cannot reject the null hypothesis. Under the null hypothesis, the fixed-effect model is less efficient and the random effect model is more favourable.

Obviously, our model assumes no time-specific effects and focuses only on individual-specific effects. The reasons we ignore the time-specific effects are that this study covers relatively short period of time, which has emphasised the important period of transition for the Chinese economy, and the involvement of time effects will further reduce the degree of freedom if we introduce dummies for the time effects.

The fixed-effect model may correct the bias of omitted variables occurred in the single cross-sectional regression by using dummy variables for provinces. However, the fixed coefficients on every explanatory variable over time does not reflect changes in the effect of variable of interest over time. Thirdly, we allow differences in slopes as well as in intercept terms over time but constant across provinces and use the seemingly unrelated regression model to see changes in the effects over time. And for the analysis by period we use

$$lnGRO_{m,j}=\alpha_m+\beta_m lnGAP_{m,j}+\delta_1 lnOPEN_{m,j}+\sum\phi_{mi}lnRELEV_{mi,j}+\mu_{m,j} \qquad (9\text{-}3)$$

where m=1, 2 and 3, standing for periods 1978-83, 1984-89 and 1990-95 respectively. We will estimate the equations by period jointly as a generalised regression by the seemingly unrelated regression.

The later two models (the panel data analysis and the seemingly unrelated regression) estimate with a panel data set. We break up the entire period 1978-1995 into three non-overlapping sub-periods, 1978-1983, 1984-1989 and 1990-1995 and average the included variables over the sub-periods. For example, the provincial growth rates in real GDP per worker by period will be $(\ln Y_{j,t0+5}-\ln Y_{j,t0})/5$. There are thus three cross-sections of provinces corresponding to the three sub-periods. In the estimation by the panel data model, we stack the data-set by variable. Each variable has three sub-period observations times 29 provinces. The sample size increases from 29 in the single cross-province regression to 87. In the estimation by the seemingly unrelated regression, we simply reset data by period. Every period, standing for every regression, has 29 observations. Then, we estimate a multivariate regression system with as many regressions as periods.

4. Basic results

The objectives of this empirical investigation are to test the hypothesis that openness affects growth through its impact on technological change and to investigate the alternative effects of openness in the process of China's growth during 1978-1995. In this section, we firstly test the hypothesis by regressing growth of real GDP per worker on the explanatory variables included in equation (9). Our estimation results by the single cross-province regression and the panel data analysis are presented in Table 1 while those from the seemingly unrelated regression estimation are reported in Table 2. Secondly, we test robustness of the results by the two-stage least squares model. Thirdly, we examine other explanatory variables included in equation 9.

4.1 Test for the effect of openness through its impact on technological change

Inclusion of openness in the estimation functions is consequently a test of its impact on technological change—growth in output after controlling for an increase in the use of domestic resources. The hypotheses about the individual positive effect on economic growth of openness cannot be rejected with the data. In the single cross-province regression, it is evident (columns 2 and 3 of Table 1) that the ratios of imports and foreign direct investment to GDP are positively related to economic growth respectively. Holding other variables constant, an increase in the ratio of imports to GDP by 1 percent will be associated with 0.165 percent increase in the subsequent economic growth rate while that in the ratio of foreign direct investment to GDP will enhance the subsequent economic growth by 0.083 percent. Economic growth is generally inelastic to the measures of openness in the single cross-province regression. And the partial effect on economic growth of the ratio of imports to GDP is relatively larger than that of the ratio of foreign direct investment to GDP.

This individual positive effect of openness on economic growth is supported by the panel data analysis (columns 4 and 5 of Table 1). The Hausman test favours the fixed-effect model involving the ratio of imports to GDP and the random effect model involving the ratio of foreign direct investment to GDP. Both the ratios of imports and foreign direct investment to GDP are found positively and significantly related to economic growth. The panel data analysis shows a stronger relationship between the measures of openness and economic growth, as magnitude of the coefficients on the measures of openness increases. An increase in the ratio of imports to GDP by 1 percent will increase the subsequent growth rate by 0.594 percent while that of the ratio of foreign direct investment to GDP will increase the rate of subsequent economic growth by 1.259 percent. The partial effect of the ratio of foreign direct investment to GDP is much larger than that of the ratio of imports to GDP. Economic growth becomes elastic to openness proxied by the ratio of foreign direct investment to GDP.

The main results from the single cross-province regression and panel data analysis indicate that openness has a positive and significant effect on economic growth. As the ratio of total investment to GDP has been controlled for in the regression, the measures of openness increase growth rates directly by enhancing the productivity of inputs. Especially in the cross-province regression, the coefficient on the ratio of total investment in fixed assets to GDP is statistically significant in the presence of the ratio of foreign direct investment to GDP.

Table 1. Regressions of log growth in real GDP per worker over 1978-1995

Explanatory Variables	Cross-sectional	Cross-sectional	Fixed-effect	Random effect
Constant	-4.224 (-1.746)	-5.471 (-2.464)		0.359 (1.405)
lnY	-0.681 (-3.920)	-0.599 (-3.590)	-0.067 (-1.470)	-0.028 (-0.824)
lnINV	0.601 (1.326)	0.925 (2.352)	0.02 (0.574)	0.048 (1.402)
lnLAB	0.138 (1.383)	0.161 (1.596)	0.064 (0.737)	0.002 (0.084)

lnIMP	0.165 (2.093)		0.594 (5.968)	
lnFDI		0.083 (1.732)		1.259 (4.276)
lnHC	0.56 (1.807)	0.463 (1.484)	-0.053 (-1.161)	-0.021 (-0.493)
Adj.R^2	0.53	0.51	0.44	0.14
Observations	29	29	87	87
Hausman Test			$\chi^2(5)=21.259$	$\chi^2(5)=4.959$

Note: Values in brackets are t ratios. Intercept terms of the fixed-effect models vary across provinces so that they are not reported in the table.

lnY = natural logarithm of real GDP per capita of the beginning year, 1978 for the cross-section regression and 1978, 1984 and 1990 for the panel data analysis

lnINV = natural logarithm of ratio of total investment in fixed assets to GDP over 1978-95 for the cross-section regression and over 1978-83, 1984-89 and 1990-95 for the panel data analysis

lnLAB = natural logarithm of total labour force over 1978-95 for the cross-province regression and over 1978-83, 1984-89 and 1990-95 for the panel data analysis

lnHC = natural logarithm of ratio of secondary school enrolment to population at the age of 15-19, 1982 for the cross-province regressions and 1982, the average of 1982 and 1995 and 1995 for the panel data analysis

lnIMP = natural logarithm of ratio of values of imports to GDP in the Chinese Yuan over 1978-95 for the cross-section regression and over 1978-83, 1984-89 and 1990-95 for the panel data analysis

lnFDI = natural logarithm of ratio of values of utilised foreign direct investment to GDP in the Chinese Yuan over 1978-95 for the cross-section regression and over 1978-83, 1984-89 and 1990-95 for the panel data analysis

The hypothesis of the individual positive effect of openness on economic growth is not supported with the sub-period data completely (Table 2). In the first two sub-periods, 1978-1983 and 1984-1989, the measures of openness are insignificant in explaining China's economic growth. The short-run insignificant correlation between openness and economic growth can be explained by the fact that there is a time lag between the implementation of imports and foreign direct investment and the realisation of their impacts.

The hypothesis about the positive effect of openness on economic growth can not be rejected in the sub-period 1990-1995 since the coefficients on the ratios of imports and foreign direct investment to GDP are significantly positive. However, the magnitude of the coefficients is negligible. An increase in the ratios of imports and foreign direct investment to GDP by 1 percent will be associated with 0.016 and 0.022 percent, respectively, increase in growth rate of real GDP per worker. The result that openness is insignificant in the first two sub-periods but significant in explaining economic growth in the final period of reforms, 1990-1995, may indicate the possible reversed causality from economic growth to openness.

Table 2. Regressions of log growth in real GDP per worker over sub-periods

Explanatory Variables	1978-1983	1978-1983	1984-1989	1984-1989	1990-1995	1990-1995
Constant	0.149 (1.152)	0.167 (1.311)	0.025 (0.217)	0.054 (0.481)	-1.343 (-7.121)	-1.3 (-8.742)
lnY	-0.03 (-2.730)	-0.028 (-2.755)	-0.027 (-2.227)	-0.024 (-2.140)	0.144 (6.778)	0.149 (8.102)
lnINV	-0.002 (-0.136)	-0.005 (-0.326)	0.036 (1.761)	0.028 (1.408)	0.005 (0.146)	0.002 (0.066)
lnLAB	0.006 (1.003)	0.005 (0.824)	0.004 (0.830)	0.004 (0.687)	0.009 (1.036)	0.007 (0.947)
lnIMP	0.005 (0.536)		0.007 (1.210)		0.016 (1.763)	
lnFDI		0.017 (0.844)		0.012 (1.608)		0.022 (3.328)
lnHC	0.016 (1.209)	0.012 (0.919)	0.005 (0.277)	0.002 (0.125)	0.06 (2.030)	0.049 (1.818)
Adj. R2	0.24	0.21	0.10	0.01	0.88	0.89
Observations	29	29	29	29	29	29

Note: see notes to Table 2. All the variables are over three sub-periods, 1978-83, 1984-89 and 1990-95.

4.2 Correction for the endogeneity of openness

The partial relationship between openness and growth found in this study does not necessarily imply that variable of interest causes growth. Harrison (1996) detects that causality between openness and growth runs in both directions by using the vector autoregressions with a panel data-set across a group of developing countries over 1960-1987[4]. The more open an economy, the higher its growth rate. But it is also true that a fast-growing economy tends to be more open.

Edwards (1992) reminds us that the measures of openness as we proxied with the ratios of imports and foreign direct investment to GDP in the study are largely endogenous. In the case of China, the ratios of imports and foreign direct investment to GDP depend on government policies, which were biased towards the coastal provinces, as well as the condition of infrastructure. As these unmeasureable variables are included in the disturbance

[4] The number of countries and time period covered in Harrison (1996) depend on the measure of openness used. The number of countries covered ranges between 17 to 51 while the time period is 1960-1987 or 1978-1988.

terms in equation (9), the ratios of imports and foreign direct investment to GDP are likely correlated with the disturbances. The equation (9) does not satisfy the assumption of the classical regression model that the explanatory variables are not correlated with the disturbances. Thus the coefficients on the endogenous variables cannot be consistently estimated by the least squares regression. The one-way fixed effect model in the previous section could have taken care of the time-invariant province-specific factors, such as the condition of infrastructure, but not the time-variant province-specific variables like the government policies. The time-variant province-specific variables included in the disturbance term are still correlated with the endogenous variables.

Moreover, the methodology we adopted in this study up to date is not able to distinguish a fast-growing economy which systematically pursues openness from a slow-growing economy which turns to openness as a remedy. It also arises from the potential endogeneity or simultaneity between growth and openness. If the fast-growing economy is systematically more likely to be in a higher degree of openness, then contemporaneous estimate of the impact of openness on growth will be overestimated. Alternatively, if the slow-growing economy turns to openness as a remedy, then such cross-sectional estimate will understate the true effect of openness on growth.

Furthermore, most studies, like Harrison (1996) and Edwards (1998), try to test the robustness of the effect of openness by including other variable additionally in the growth regression. Srinivasan (1995) argues that it is problematic conceptually to test the robustness of a relationship between a dependent variable and an explanatory variable of interest by varying other explanatory variables in the regression. In principle, the use of different sets of variables to explain the same dependent variable implies the specification of different models. The sign and the statistical significance of the coefficient on a given variable of interest are thus model specific. The relationship between a dependent variable and an explanatory variable of interest is not compatible across different models.

In this section we use the two-state least-squares model to test the robustness of the positive effect of openness and to overcome the above-mentioned reversed causality, endogeneity and simultaneity. Basically the two-stage least squares method consists of using as the instruments for openness the predicted values in a regression of openness on exogenous variables.

Specifically, we will firstly regress the endogenous variables, the ratios of imports and foreign direct investment to GDP, on exogenous variables which are correlated with the endogenous variables but uncorrelated with the disturbance term. For the measures of openness in equation (9), the rest explanatory variables included, namely the initial level of real GDP per worker, the ratio of total investment in fixed assets to GDP, human capital endowment and total labour force, are exogenous. Additionally, we introduce two more variables, coastal dummy and ratio of telephone sets to total population[5]. They are also exogenous determinants of the ratios of imports and foreign direct investment to GDP. The coastal dummy roughly reflects the policies biased towards the coastal provinces while the ratio of telephone sets to population partially represents the condition of infrastructure. The predicted values of the measures of openness can be obtained from the estimated regression model.

Secondly, we replace the actual values of the ratios of imports and foreign direct investment to GDP with the predicted values in the regression of equation (9) by ordinary least squares.

Results are presented in Table 3. Not only are these results consistent with the OLS results (reported in Table 1), but also they are in each case somewhat larger than the OLS results presented previously. Our early results of the positive effect of openness are robust. It implies that there is a positive and significant effect of openness on growth even if the endogeneity of openness or the simultaneity between openness and growth is taken into account. Based upon the results from the two-stage least squares, we may also say that openness caused China's

[5] Coastal dummy and the ratio of telephone sets to total population can be used as instruments, because they are correlated with both the endogenous variables (the measures of openness) and the dependent variable (the subsequent rates of economic growth) while uncorrelated with the disturbances.

economic growth during 1978-1995.

Table 3 Estimation of growth equations by the two-stage least squares model

Explanatory variables	Cross-province	Cross-province	Fixed-effect	Fixed-effect
Constant	-2.011 (-0.728)	-3.394 (-1.430)		
lnY	-0.78 (-4.424)	-0.667 (-4.130)	-0.059 (-1.270)	-0.084 (-1.718)
lnINV	0.208 (0.409)	0.655 (1.644)	-0.034 (-0.839)	0.073 (0.337)
lnLAB	0.067 (0.629)	0.077 (0.730)	0.033 (0.370)	0.06 (0.648)
lnIMP	0.272 (2.545)		0.9 (5.682)	
lnFDI		0.163 (2.610)		2.292 (4.845)
lnHC	0.646 (2.202)	0.497 (1.688)	-0.067 (-1.428)	-0.057 (-1.156)
Adj. R^2	0.50	0.45	0.42	0.35
Observations	29	29	87	87
Hausman Test			$\chi^2(5)=27.07$	$\chi^2(5)=7.889$

Note: See notes to Table 2. Instruments are coastal dummy, ratio of telephone sets to total population, lnY, lnINV, lnLAB and lnHC for the single cross-province regressions. In the panel data analyses, we let the fixed-effect models to take care of the time-invariant province-specific factors and include a time trend, ratio of telephone sets to total population and the rest explanatory variables as instruments.

4.3 Results on other explanatory variables

Our earlier conjecture about the correlation between economic growth and the technological gap between domestic and world economies is borne out. The coefficient on the initial level of real GDP per worker (Table 1), proxied for the knowledge gap, are negatively significant. As predicted by the model, with other things given a province with a larger technological gap will tend to "catch-up" faster. Table 1 shows that a province with a lower initial level of real GDP per capita will tend to grow 0.681 and 0.599 percentage point faster, respectively, in the regressions involving the ratios of imports and foreign direct investment to GDP. The panel data analysis does not support, however, the hypothesis of catch-up as the magnitude of the coefficients on the initial levels of income is negligible and the coefficients are statistically insignificant.

This empirical study does not support the hypothesis of a scale effect (Table 1). Although total labour force is positively related to the subsequent economic growth, the coefficient on total labour force is statistically insignificant. The empirical absence of a scale effect implies that economic growth or the growth of the varieties of intermediate goods is not dependent on labour endowment[6]. In the case of China with a huge population, it is less likely for scientists to interact with each other. Thus an increase in labour endowment unlikely reduces the cost of an invention by sharing it effectively.

Human capital investment, proxied by the secondary schools enrolment rates, is found positively and significantly related to economic growth in the single cross-province regression. Table 1 shows that given other things, an increase in human capital investment by 1 percent will be associated with 0.56 and 0.463 percent increase in the subsequent economic growth respectively in the cross-province regressions involving imports and foreign direct investment.

However, the correlation between economic growth and human capital investment is insignificant in the panel data analyses. This result confirms Knight et al. (1993) and Islam's (1995) finding that time-series dimension in the secondary school enrolment rates is not a preferred proxy in estimating the growth effect of human capital investment. Meanwhile, we observe from SURE model (Table 3) that the secondary school enrolment rate is insignificant in explaining economic growth in the periods of 1978-1983 and 1984-1989, while the correlation between the enrolment rate and economic growth is statistically significant during 1990-1995. These results, on the one hand, seem to support Knight et al. (1993) and Islam's (1995) claim that the secondary school enrolment rate may not be a good proxy for the human capital investment when relatively short intervals are compared. On the other hand, they may suggest that there is a time lag for the role of human capital in the growth process.

[6] Under the assumption that physical capital is an aggregate of different varieties of intermediate goods, economic growth or growth in the varieties of intermediates should depend on labour endowment as in our equations (7) and (7)'. Currie, Levine, Pearlman and Chui (1999) prove that economic growth or growth in the varieties of intermediate goods is not dependent on labour endowment if knowledge capital is proportional to the ratio of the varieties of intermediate goods to labour endowment.

This empirical model is derived from our theoretical framework in the previous section. Unfortunately, from our regression results based on the data we are generally unable to detect the separate influence of the ratio of total investment to GDP. This could be due to the collinearity between explanatory variables. Likewise, Barro (1991), DeLong and Summers (1991) and Levine and Renelt (1992) show that impact of education on growth is reduced or lost when investment in physical capital and other factors are included, because investments in education and physical capital, in particular, are positively correlated. Blomstrom, Lipsey and Zejan (1994) find that adding foreign direct investment to the other variables in their regression tends to lower substantially the influence of the coefficient for the fixed investment ratio, particularly in the sample of developing countries. The collinearity between explanatory variables will be examined in the following section.

5. Alternative specifications

5.1 Interaction between openness and human capital endowment

The results in the previous section appear to suggest a persistent relationship between openness and economic growth during 1978-1995. However, some have argued that openness is primarily associated with growth in economies with enough human capital to effectively absorb new technology. Levine and Raut (1992) in an analysis of a set of semi-industrialised countries provide some evidence for the hypothesis that a positive impact of educational investment on growth depends on increasing openness. Thus, the impact of openness on growth, if any, probably works through its interdependence with other factors that take part in the growth process.

We here explore whether human capital may interact with imports and foreign direct investment to accelerate growth with Chinese data. Specifically, we examine the interaction between the secondary school enrolment rates and the measures of openness and test their joint significance in explaining variation in growth of per worker output. In such a specification, openness is associated with both higher productivity growth and higher returns to human capital. An alternative interpretation is that the benefits from openness are higher for a more educated population.

Table 4. Cross-sectional regressions of log growth in per worker real GDP in the presence of interaction terms between human capital and openness

Explanatory Variables	(2)	(3)	(4)	(5)
Constant	-3.91 (-1.542)	-4.682 (-1.252)	-5.391 (-2.406)	-5.23 (-1.173)
LnY	-0.703 (-3.930)	-0.651 (-2.526)	-0.614 (-3.633)	-0.649 (-2.392)
LnINV	0.599 (1.315)	0.61 (1.308)	0.915 (2.318)	0.896 (2.137)
LnLAB	0.136 (1.348)	0.143 (1.352)	0.157 (1.544)	0.149 (1.304)
LnIMP*LnHC	0.043 (2.077)	-0.057 (-0.163)		
LnFDI*LnHC			0.022 (1.742)	0.075 (0.239)
LnIMP		0.382 (0.287)		
LnFDI				-0.202 (-0.169)
LnHC	0.523 (1.704)	0.607 (1.414)	0.487 (1.555)	0.544 (1.170)
Adj. R^2 Observations	0.53 29	0.51 29	0.51 29	0.49 29

Note: see notes to Table 2.

lnIMP*lnHC = the product of natural logarithm of the ratio of imports to GDP over 1978-95 and natural logarithm of 1982 secondary school enrolment rates

lnFDI*lnHC = the product of natural logarithm of the ratio of foreign direct investment to GDP over 1978-95 and natural logarithm of 1982 secondary school enrolment rates

Results in columns 2 and 4 of Table 4 show that we replace the measures of openness by the products of human capital investment and the measures of openness in the cross-province regressions. The coefficients on the interaction terms are positive and statistically significant. However, the magnitude of the coefficients is very small, being 0.043 and 0.022 respectively. The significance of the interaction terms may be the result of the omission of other relevant factors, in particular, the measures of openness.

It is necessary to include the measures of openness and human capital investment individually alongside their products. In that way, we can test jointly whether these variables affect growth by themselves or through the interaction terms. Such specifications are adopted in columns 3 and 5 of Table 4. The results show that the coefficients on the interaction terms are insignificant. Thus the effect of interaction terms on economic growth is not robust. The interaction terms in columns 2 and 4 only capture the effects of the measures of openness which are omitted in the cross-province regressions.

Table 5. Regressions of log growth in per worker real GDP in the presence of interaction terms between human capital and openness in the panel data analysis

Explanatory Variables	Fixed-effect	Fixed-effect	Random effect	Fixed-effect
Constant			0.375 (1.488)	
lnY	-0.063 (-1.409)	-0.033 (-0.789)	-0.029 (-0.863)	-0.056 (-1.610)
lnINV	0.015 (0.457)	0.006 (0.202)	0.041 (1.237)	0.002 (0.082)
lnLAB	0.069 (0.812)	0.126 (1.568)	0.001 (0.054)	0.168 (2.508)
lnIMP*lnHC	0.143 (6.263)	1.34 (3.554)		
lnFDI*lnHC			0.336 (4.743)	6.465 (7.647)
lnIMP		-5.112 (-3.179)		
lnFDI				-24.874 (-7.245)
lnHC	-0.058 (-1.293)	-0.09 (-2.164)	-0.025 (-0.596)	-0.113 (-3.133)
Adj. R^2	0.46	0.54	0.15	0.67
Observations	87	87	87	87
Hausman Test	$\chi^2(5)=21.03$	$\chi^2(6)=19.534$	$\chi^2(5)=4.935$	$\chi^2(6)=29.682$

Note: see notes to Tables 2 and 5. The interaction terms are over 1978-83, 1984-89 and 1990-95.

In the panel data analysis, we also find a positive and significant effect of the interaction terms on economic growth (columns 2 and 4 of Table 5). Each one percent increase in the interaction terms between the measures of openness and the secondary school enrolment rate will increase the rate of growth in real GDP per worker by 0.143 and 0.336 percent respectively. In the regressions including the measures of openness and the enrolment rates individually alongside their products (columns 3 and 5 of Table 5), the coefficients on the interaction terms are still positive and significant while those on the measures of openness are significantly negative. These results indicate that human capital investment and the measures of openness affect growth through their interaction terms in the regressions using the information on variation within provinces over time.

5.2 Openness and domestic physical investment

Levine and Renelt (1992) find a positive correlation between the share of trade in GDP and the share of total investment in GDP. They use this result to suggest that linkages between trade and growth may occur through investment, instead of through improved resource allocation and openness may be important only in so far as it provides greater access to investment goods. To investigate the effect of openness through the accumulation of capital, we regress the ratios of total investment to GDP on the measures of openness and other variables. The results are presented in Table 6.

Table 6. Regressions of log ratio of total investment to GDP

Explanatory Variables	Cross-province	Cross-province	Fixed-effect	Fixed-effect
Constant	4.63 (8.554)	4.583 (6.812)		
lnY	-0.099 (-1.310)	-0.037 (-0.433)	0.231 (1.308)	0.215 (1.142)
lnLAB	-0.165 (-5.511)	-0.18 (-4.836)	-0.06 (-0.176)	0.003 (0.009)
lnIMP	0.111 (4.062)		1.481 (4.373)	
lmFDI		0.05 (2.224)		3.518 (3.334)
lnHC	0.238 (1.823)	0.23 (1.484)	0.165 (0.925)	0.214 (1.133)
Adj.R2	0.68	0.56	0.60	0.55
Observations	29	29	87	87
Hausman Test			$\chi^2(4)$=16.82	$\chi^2(4)$=15.19

Note: see notes to Table 2.

Columns 2 and 3 report the results from the cross-province regressions. Although the ratios of imports and foreign direct investment to GDP are positively and significantly correlated to the ratio of total investment in fixed assets to GDP, magnitude of the coefficients on the ratios of imports and foreign direct investment are negligible. An increase in the ratios of imports and foreign direct investment by 1 percent will be associated with, respectively, 0.111 and 0.05 percent increase in the ratio of total investment to GDP. Since the data on total investment include imported capital goods and foreign direct investment, the estimated coefficients on the ratios of imports and foreign direct investment, far less than 1, may imply that the ratios of imports and foreign direct investment to GDP do not affect the total level of investment.

The negligible relationship between the measures of openness and the ratio of total investment in fixed assets confirms our earlier finding that the measures of openness, especially the ratio of foreign direct investment to GDP, affect China's economic growth during 1978-1995 through its impact on technological change (improved allocation of resources) in the single cross-province regressions. The earlier statistically insignificant coefficient on the ratio of total investment in fixed assets to GDP (reported in column 2 of Table 1) indicates that the ratio of total investment in fixed assets to GDP does not explain China's economic growth during 1978-1995 when the ratio of imports to GDP is controlled in the single cross-province regressions.

The results from the panel data analyses (reported in columns 4 and 5 of Table 6) show a positive relationship between the measures of openness and the ratio of total investment to GDP. In the panel data analyses, both the ratios of imports and foreign direct investment to GDP are positively and significantly related to the ratio of investment to GDP and openness increases investment more than one-to-one. An increase in the measures of openness by 1 percent will be related to the increase in the ratio of investment by 1.481 and 3.518 percent respectively. These results indicate that openness exerts a positive effect on domestic investment, presumably because the attraction of complementary activities dominates the displacement of domestic competitors. This is an indirect effect of openness on growth, since it operates through "pulling in" other sources of investment.

As there is a positive and significant correlation between the measures of openness and the ratio of total investment in fixed assets to GDP, we can explain the earlier statistically insignificant coefficients on the ratio of total investment in fixed assets to GDP in the panel data analysis (reported in columns 4 and 5 of Table 1) as follows. The effect of the ratio of total investment in fixed assets on China's economic growth during 1978-1995 was taken over by the measures of openness and the measures of openness accelerated economic growth through enhancing the accumulation of capital in the panel data analyses using the information on variation within provinces over time.

These results in section 5 may be summarised as follows. First, the measures of openness accelerate economic growth through its impact on technological progress when the cross-province difference in openness is investigated as the single cross-province regressions do. (The single cross-province regression uses the cross-sectional information of the variables averaged over 18 years during 1978-1995.) The effect of openness on economic growth is independent from the interaction term with human capital endowment.

Second, openness to trade and foreign direct investment affects economic growth through enhancing the accumulation of capital when the time series dimension in openness is examined as the panel data analysis does. (The panel data analysis uses the time-series dimension information of variables averaged over intervals of six years.) Openness affects economic growth through the interaction with human capital endowment.

6 Conclusion

In this study, the theoretical tie between China's economic growth and the measures of openness was hypothesised to run through technological progress (improved allocation of resources). In order to test this hypothesis, the use of domestic inputs of production, such as the ratios of total investment in fixed assets and human capital to GDP and total labour force, has been controlled for in the regressions. The hypothesis can not be rejected with the data as there is a positive and significant relationship between China's economic growth and the measures of openness both in the cross-province regressions and the panel data analyses. Moreover, the results from the two-stage least squares model also support the positively significant correlation between the measures of openness and the subsequent economic growth in the presence of domestic inputs of production in both the cross-province regression and the panel data analysis.

We further investigated alternative specifications of the effects of openness. Firstly, we examined the complementary effects between openness and human capital endowment. The positive correlation between China's economic growth and the interaction between the measures of openness and human capital endowment is not robust in the single cross-province regressions controlling for individual effect of openness. It seems to suggest that openness has an individual positive effect, instead of a joint effect with human capital endowment, on China's economic growth during 1978-1995 in the cross-province regressions. However, our panel data analysis controlling for the individual effect of openness showed a significantly positive correlation between economic growth and the interaction terms. This suggests that the impact of openness on growth probably works through its interdependence with human capital that takes part in the growth process in the panel data analysis.

Secondly, we investigated whether openness affected China's economic growth during 1978-1995 through enhancing the accumulation of capital. In the cross-province regressions using the information on the variables averaged over 1978-1995, the correlation between the ratio of total investment in fixed assets to GDP and the measures of openness is negligible. Thus, our earlier hypothesis of the positive effect of openness through its impact on technological change is supported. It may indicate that openness affects economic growth through technological progress in the long run.

However, in the panel data analysis using the time-series dimension information on the variables averaged over sub-periods of six years, we found a significant and positive correlation between the ratio of total investment to GDP and the measures of openness. And the magnitude of the coefficients on the ratios of imports and foreign direct investment is more than one. It may suggest that openness affected China's economic growth during 1978-1995 through pulling in other sources and enhancing capital accumulation in the short run.

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Appendix 1. Data description

Gro This variable is defined as the annual growth rate in real GDP per worker averaged over a period of years by taking natural logarithm of both sides of $Y_{t0+T}=Y_{t0}(1+r)^T$ where Y is real GDP per worker and T is the number of years in the period under study.

Gap In the literature of catch-up debate, such as Verspagen (1991), three variables are involved since it is not possible to directly measure the technological gap. GDP per capita, education attainment and patents are proxied for a technology gap, the social capability and innovative activity respectively. We will use the natural logarithm of real GDP per worker of the beginning year of the period under study. The idea is that a province with lower initial income per capita has a larger gap and thus will tend to grow faster. It is expected then that in the regression where real GDP per capita is included its coefficient will be negative.

Open According to our analytical framework, imports and foreign direct investment play a role in the process of technological progress. Variables measuring openness of the provincial economies relevant to technological progress should preferably be imports of and foreign direct investment in machinery and transportation equipment from advanced nations. The flow of foreign direct investment is a measure of the flow of disembodied technology while imports of machinery and transport equipment are a measure of the inflow of technology embodied in new machinery.

Because we failed to find data on imports of and foreign direct investment in machinery and transportation equipment at the provincial level, we have to substitute them with data on general imports and values of utilised foreign direct investment. Data on general imports would not make a big difference because China restricted its imports very much in the most years of the reform period and only capital goods and key materials were allowed to be imported for the use of domestic production and for exports. Statistics[1] shows that imports of

[1] Source: Value of imports by category of commodities (Customs statistics), Statistical Yearbook of China, compiled by State Statistical Bureau, People's Republic of China, 1998

chemicals related products and machinery and transport equipment accounted for 59.3 percent of total imports during 1980-1995 at the national level. The imports of chemicals related products and machinery and transport equipment most likely embody advanced technology relative to domestic counterparts.

Meanwhile, statistics[2] also shows that 96 percent of the amount of foreign direct investment actually utilised in 1985 were absorbed by Ministry of Coal Industry, Ministry of Post and Telecommunication, Petroleum and Chemical Corporation of China and Offshore Petroleum Corporation of China. The utilisation of foreign direct investment by Ministry of Foreign Trade, State Tourism Bureau and others accounted for the rest 4 percent in the same year. It means that most of foreign investment was used in the production in 1985. Table 1 reports the cross-sector distribution of foreign direct investment in China since 1988. The sectors which were most in need of the disembodied technology, such as industry, geological exploration, transportation, post and telecommunication, education, culture and art and scientific research and polytechnic services, attracted 78.6, 85.6, 81.8, 59.1, 48.2 and 70 percent of total foreign investment in China in 1988, 1990, 1991, 1992, 1994 and 1995 respectively. Foreign direct investment should have at least brought in advanced management, no matter whichever sector it is directed to.

Table A1 Cross-sector distribution of foreign direct investment in China (US$10,000)

	1988	1990	1991	1992	1994	1995
Total	529,706	659,611	11,976,820	58,123,510	11,143,566	91,281,153
1	20,886	12,225	219,960	678,130	119,147	173,578
2	402,146	556,918	9,622,690	32,666,730	5,117,368	61,647,763
3	164	40	-	2,650	-	-
4	11,881	18,108	134,200	1,838,580	387,837	191,836
5	9,116	3,646	94,950	1,543,430	148,991	169,698
6	6,424	10,660	174,240	1,443,840	460,647	342,665
7	53,016	45,247	1,503,710	18,079,640	4,377,115	1,783,542
7.1	-	-	-	-	148,153	95,377
8	528	3,798	64,020	395,260	47,748	83,741
9	4,444	506	55,990	96,730	45,173	34,496
10	739	3,195	18,550	61,850	58,775	27,775

[2] Source: China Trade and Price Statistics, compiled by State Statistical Bureau, People's Republic of China, 1987

11	1167	-	-	7,540	-	-
12	19,195	5,268	88,510	1,309,130	380,765	156,059

Note: 1= Agriculture, Forestry, Husbandry and Fishery
2=Industry
3=Geological exploration
4=Construction
5=Transportation, Postal and Telecommunication Services
6=Commerce and Catering
7=Real Estate, Public Utilities and services
7.1=Tourist Hotels
8=Health Care, Sports and Social Welfare
9=Education, Culture and Art
10= Scientific Research and Poly-technical Services
11=Finance and Insurance
12=others

In the Chinese statistics, total value of imports is the total value of commodities imported through China's custom by state-owned and collective enterprises, sino-foreign joint ventures, contractual joint ventures and sole proprietorship foreign ventures. Data on imports are complete for all provinces, and the values of imports are measured by the U.S. dollar. We first transform the values of imports to the Chinese RMB Yuan by using the exchange rates from 1978 to 1995 respectively. Data on the exchange rate between the U.S. dollar and Chinese RMB Yuan are available from 1981 to 1995 in the Chinese statistics. We use the rate of 1981 for the years 1978 to 1980. Secondly we derive the provincial ratios of imports to GDP by dividing the sum of values of imports by province in the Chinese Yuan with the sum of provincial GDP in current price over the period under study. Then we take natural logarithm of the ratios.

Foreign direct investment is the realised amount of funds invested from abroad in the U. S. dollar. Since foreign direct investment was introduced in the Southeast of China in 1978 and flourished in the whole country only in late 1980s, data on the utilised foreign direct investment are limited to a few coastal provinces in the early years of the reform period and are only complete since the late 1980s. We also transform the values of utilised foreign direct investment in the U.S. dollar into Chinese RMB Yuan and introduce the ratio of foreign direct investment to GDP into the regression[3]. As usual, we take natural logarithm of the

[3] We simply treat missing values of foreign direct investment in the early years for some provinces as zero.

ratio. The coefficients on both the measures of openness are expected to be positive in the long run.

RELEV Our growth equation (7') of the previous section contains a scale effect: the larger labour endowment, L, the higher rate of economic growth. This scale effect arises because a new product either through the domestic innovation or the imitation of foreign technology can be used in a non-rival manner across the entire economy according to our assumption of spillovers of knowledge at the provincial level. The larger the economy, represented by the labour endowment, the lower the cost of an invention per unit of the labour endowment. An increase in labour endowment therefore has the same effect on economic growth as a decrease in the cost of invention. We introduce it into the regressions by natural logarithm of the absolute number of total labour force by province. The sign of labour force is expected to be positive too.

Relevant to the households' preference parameters, ρ and θ, in equation (7') are investment in fixed assets and human capital. As usual, we use the ratio of total investment in fixed assets to GDP and further take natural logarithm of the ratio. We expect that the ratio of total investment in fixed assets to GDP is positively related to economic growth.

Investment in human capital reflects the level of human capital endowment. We proxy investment in human capital by the secondary school enrolment rates, the proportion of population between 15 and 19 years old who are enrolled in the secondary schools. Human capital endowment is relevant to our investigation of an economy's ability to absorb foreign technology through foreign trade and investment. The interactions between the endowment of human capital and the measures of openness may accelerate growth. It is expected that the secondary school enrolment rates and the interaction term between the measures of openness and the secondary school enrolment rate are positively related to economic growth.