

Capital goods imports and long-run growth in China¹

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Abstract

In this paper, we analyse the role played by capital goods imports in the long-run growth of the Chinese economy. We find evidence that the ratio of imported to domestic capital goods, that is, the composition of investment, as well as the capital accumulation (both physical and human) were key determinants of the long-run growth rate of per capita GDP from 1965 to 2007. The cointegrated VAR model was used to overcome the potential endogeneity problem and the existence of stochastic trends in the variables. Our results are consistent with the hypothesis that the link between trade openness and long-run growth operates mainly through imports. This finding supports some recent developments of Schumpeterian models of growth, which state that, in the early stages of growth, government intervention to encourage an investment-based strategy, with emphasis on large investment efforts and the adoption of foreign technology, could be an appropriate strategy for development.

JEL Classification: O40, O53, F1

Key Words: Openness, imports of capital goods, capital accumulation, growth, China

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1. Introduction

Today, nobody doubts that openness to trade is a source of long-run economic growth. However, understanding the channels through which trade can enhance growth remains a widely debated question. One of the key points of such discussion lies in the fact that it is not easy to isolate the channels that can produce the expected positive impact of openness on growth and that these channels may differ both from country to country and depending on the stage of development. Economists have made an effort to disentangle this piece of the puzzle in the international economics literature, but there are still questions that have still not be dealt with and need answering to be able to fully understand the empirical relation between trade and growth.² For example, is enhanced growth always primarily due to the impact of openness on exporting or on importing activity? Has increasing competition and the improvement of scale associated with increased trading volume (exports and imports) been the most valuable conduit of growth? Or is the positive effect of openness on growth to be found in the improvement of the country's technological level due to the imported foreign intermediate and capital goods? In this paper, we address some of these questions in a case study: the Chinese economy over the last few decades.

From the standpoint of growth models, it seems that the links between trade openness and growth should be stronger through imports than exports, and this is especially true for certain types of imports. First of all, in a wide range of growth models, sustained growth will only be possible in the long run if there are large sustained productivity gains to counteract the tendency towards the diminishing returns induced by the accumulation of capital. These gains can arise from two channels: from investment in R&D and the innovation process that incorporate technological progress into productive activity, on the one hand, and from a more efficient capital accumulation, on the other. But, as pointed out by Aghion and Howitt (1998), the critical question is that “capital accumulation and innovation should not be regarded as distinct causal

² For a recent survey of the literature on trade liberalization and economic performance in developing countries, see Santos-Paulino (2010).

factors but as two aspects of the same process”.³ In fact, new technologies are usually embodied in intermediate and capital goods and it is through capital accumulation that they gradually become incorporated into the economy.⁴ And indeed for developing countries trade openness, and more specifically intermediate and capital goods imports, can help to improve both channels and thereby sustain productivity gains and growth in the long run.

International trade theory tells us that, regardless of the nature of the sources of comparative advantage, countries tend to specialize and export goods that are produced more efficiently, thus achieving static gains from trade. Developing economies often have a comparative advantage in the production of unskilled or semi-skilled labour-intensive goods, whereas developed countries have an advantage in the production of capital and technology intensive goods. It is well known that the majority of production and hence of world exports of capital goods are concentrated in a few developed countries, while developing countries tend to be importers of such goods.⁵ Thus, for developing countries, imports of capital goods are a way to improve both the efficiency of capital accumulation⁶ and the efficiency of domestic production processes due to the technological progress embodied in these imported goods.⁷ Additionally, there is a growing body of literature suggesting that, in open economies, the interaction between the domestic and foreign processes of innovation and growth may itself become a new engine of long-run growth.⁸ However, this same literature emphasizes that the possible relationship of complementarity or substitutability between domestic and foreign innovation depends on the domestic institutions and policies of different countries and their stage of development. As

³ Aghion and Howitt (1998), p.85.

⁴ At the same time, many authors have underlined the empirical significance of machinery and equipment investment in economic growth. See for example the seminal works by De Long and Summers (1991, 1992) and, for the Chinese case, Herrerias and Orts (2010).

⁵ According to Keller (2004), “for most countries, foreign sources of technology are of dominant importance (90 per cent or more) for productivity growth”. In similar terms Eaton and Kortum (1996) stated that more than 50 per cent of growth in some countries can be attributed to innovation originated in countries like the United States, Germany or Japan. See also Eaton and Kortum (2001).

⁶ See Lee (1995) and Mazumdar (2001).

⁷ See Aghion and Howitt (1998), Grossman and Helpman (1991a), Rivera-Batiz and Romer (1991), Coe et al. (1997), Goh and Olivier (2002) or Caselli and Wilson (2004).

⁸ See for example Acemoglu, Aghion and Ziliboti (2006), Aghion and Howitt (1998, 2005), Grossman and Helpman (1991b) or Rivera-Batiz and Romer (1991).

stressed in Acemoglu et al. (2006), in the early stages of growth, government intervention to encourage an investment-based strategy (with the emphasis on large investment efforts and adoption of foreign technology) might be appropriate to successfully enhance productivity and output growth even at the expenses of some non-competitive arrangements or market rigidities.

However, despite this theoretical basis, a significant part of the empirical literature has focused on the analysis of what has become known as the "export-led growth hypothesis". However, this is probably not surprising in view of the successful growth experienced by the newly industrialized East Asian countries in the 1960s, based on trade liberalization and export promotion (World Bank, 1993).⁹ Nevertheless, a number of authors remain sceptical about the role played by exports as a key factor in the growth of these countries.¹⁰ Thus, Rodrik (1995) argued that the rapid growth undergone by these economies was caused more by the acceleration of investment, the boom in trade being a consequence rather than a cause of that process.¹¹ Given the comparative disadvantage in capital and technological goods of these countries, the investment boom required an increase in imports and, given the foreign exchange constraints, a corresponding increase in exports. For some authors, even countries with a strong export orientation have to rely on imported technology as a mechanism for developing the local technological capabilities in order to increase productivity and become competitive in the international markets.¹²

Our claim is that the history is not very different in the case of China and that, above all, imports of capital goods have been an additional source of growth. In fact, our empirical evidence indicates that there is a direct relationship between the relative proportion of foreign to

⁹ A recent review of the literature that discusses the positive effects of trade liberalization can be seen in Baldwin (2003) and Greenaway and Kneller (2007).

¹⁰ For example, Thangavelu and Rajaguru (2004) found that there is no causal effect from exports to productivity growth for Hong Kong, Indonesia, Japan, Taiwan and Thailand. In addition, Lawrence and Weinstein (2001) were unable to find support for the view defending export-led growth in Japan and in their study they suggested that an important channel of growth has been neglected in this case: imports.

¹¹ See also Rodrik (1999) and Rodriguez and Rodrik (2001).

¹² See Mody and Yilmaz (2002) and Busse and Groizard (2008). Nevertheless, there are also some studies that suggest that the relationship between imports and economic growth is weak (Harrison, 1996; Quah and Rauch, 1990) or inexistent (Levine and Renelt, 1992).

domestic intermediate and capital goods used in the local production processes in China and its per capita GDP growth rate. Thus, instead of the cross-country approach taken by most empirical studies, which highlights the aspects that seem important to explain the average growth differences between countries, this paper focuses on just one single developing country, China, over the period 1965-2007. The approach used to conduct the analysis is multivariate time series estimation (the cointegrated VAR model).

It is well known that China has developed its innovation strategy by combining imports of technology with domestic research and development.¹³ Imports of intermediate and capital goods have played a significant role and have shown different stages in the process of growth and development in China (Shi, 1998). However, the Great Leap Forward supposed a sudden break away from this policy, with a sharp drop in the share of the imports of capital goods in China's total imports (see Figure 1). Furthermore, after the failure of the Great Leap Forward, there was a change in the suppliers of these goods (from Russia to technologically more advanced countries like Japan and United States). Moreover, levels that would remain relatively stable throughout the period under consideration were only reached from 1965 or 1966 onwards. As shown in Figure 1, from 1965 to 2007 (the last year considered in this work), the imports of intermediate and capital goods in China accounted for more than 80% of total imports, which gives an initial idea of the potential importance of this source of growth for the Chinese economy. To the best of our knowledge, there is no empirical evidence that analyses the importance of those imported goods as a source of long-run growth in the Chinese economy. This study attempts to cover this gap in the empirical literature on China's economic growth.

Insert Figure 1 about here

The structure of the paper is as follows. In section 2, we outline a basic model, which guides our empirical analysis and helps us in the interpretation of the results. In section 3, we provide

¹³ See Yao and Morgan (2008).

the empirical analysis with the data description and methodological issues, as well as the results. Conclusions and some policy implications are drawn in section 4.

2. Theoretical Considerations

For the sake of brevity, in this section we outline the Schumpeterian theory of growth developed in Aghion and Howitt (1992, 1998), emphasizing not only on the role played by local innovation but also on the possibility that firms can benefit from technology transfer from abroad through imitation or adoption of foreign technologies.¹⁴ As we will see, this extension of growth models with quality-improving innovations provides us with a systematic analytical framework with which to analyse the role played by imports of capital and intermediate goods from technologically more advanced countries in the investment-based strategy of development pursued by China. This strategy has encouraged investment and technology adoption and imitation from abroad, with successful results despite the costs associated with maintaining some market rigidities and “non-competitive” arrangements. However, this theory also tells us that this strategy, which seems suitable in the early stages of development, could be responsible for slowing down growth when the economy becomes more advanced and gradually approaches the world technology frontier.

Such models consider an economy with different industries. The output per worker at the industry level is given by a Cobb-Douglas production function, which depends on a productivity parameter, A_{it} , and a unique intermediate good used in this sector, K_{it} . It is easy to show that if all industries are ex ante identical, the aggregate per-worker output of this economy, Y_t , depends on aggregate capital stock, K_t , and on the labour augmenting productivity factor, A_t , that is:

$$Y_t = A_t^{1-\alpha} K_t^\alpha, \quad 0 < \alpha < 1 \quad (1)$$

where A_t is equal to the unweighted sum of the sector specific A_{it} 's.

¹⁴ See, for example, section 3 of Aghion and Howitt (2005), Aghion and Howitt (2006) and Acemoglu et al. (2006). In this section we follow the review of the Schumpeterian framework by Aghion and Howitt (2006).

It is easy to show that in this economy the long-run growth rate is given by the growth rate of A_t . Taking logs and differentiating from (1), the growth rate of Y , $g_t(Y)$, will be:

$$g_t(Y) = (1 - \alpha)g_t(A) + \alpha g_t(K) \quad (2)$$

where $g_t(A)$ and $g_t(K)$ are the growth rates of productivity and capital stock respectively.

To characterize the dynamics of capital stock we should take into account the consumption side of the economy. For the sake of simplicity, let us assume that the saving rate, s , is fixed and exogenously given,¹⁵ then the growth rate of the capital stock will be:

$$g_t(K) = \frac{sY_t}{K_t} = s \left(\frac{A_t}{K_t} \right)^{1-\alpha} \quad (3)$$

where, additionally, we are assuming that there is no depreciation.

Thus, at each date t , given the initial stock of capital, the growth rate of capital depends on the rate of saving and on the labour-augmenting productivity level. Taking logs and differentiating (3) again, it is easy to see that in the steady state, the long-run stability of $g_t(K)$, would require that $g_t(K) = g_t(A)$. Then, making use of this condition together with (2), we can show that the equilibrium (steady-state) growth rate of this economy will be the same as the growth rate of productivity, that is:

$$g_t(Y) = g_t(A) \quad (4)$$

Additionally, in Schumpeterian theory, the growth rate of A_t depends endogenously on the rate of innovation of the economy, which depends on the stock of past innovations and on the set of institutions and policies in use at each date t . In this type of models only the successful innovator firm, producing the most efficient version of each intermediate good (highest A_{it}), remains active and consequently produces and sells the intermediate good to the final industry. Each innovation improves the quality of the intermediate good, thus increasing the associate productivity from A_t to A_{t+1} in the next period. There are two ways in which firms can improve

¹⁵ Alternatively, the consumption behaviour can be represented by a function of inter-temporal utility, but the assumption of an exogenously fixed saving rate is sufficient to perform a correct approximation of the data in the long run. For more details, see section 1.2 in Aghion and Howitt (1998).

the productivity of the economy in this kind of models: by bringing out new local innovations (leading-edge or indigenous innovations) or by imitating foreign technologies (implementation innovations). Both kinds of innovations can occur at different frequencies.¹⁶ A leading-edge local innovation improves the quality of the intermediate input on a scale of $\gamma > 1$, that is, once the new intermediate good is put to use, the productivity parameter shifts from A_t to γA_t . The magnitude of γ depends on the entrepreneur's skills and the local institutional framework. Similarly to leading-edge innovations, the imitation of and adaptation to foreign technologies improves the productivity by catching up on the foreign productivity parameter $A_t^f > A_t$. Finally, if we consider that leading-edge innovation occurs with probability χ_n and successful adoption of foreign technology with probability χ_m , then the dynamics of the aggregate productivity will be expressed as:¹⁷

$$A_{t+1} - A_t = \chi_n(\gamma - 1)A_t + \chi_m(A_t^f - A_t) \quad (5)$$

The two terms on the right-hand side of (5) reflect the two dimensions that depend on the dynamics of productivity. The first approximates the innovation capacity of domestic entrepreneurs, while the latter reflects the ability to adopt or imitate foreign technology.

The second term in equation (5) also indicates how relevant the technological gap is for the growth of developing countries. It depends on the magnitude of the distance between the body of local knowledge and the state of world technology, $(A_t^f - A_t)$, as well as the appropriate institutions and policies that stimulate investment and the adoption of foreign technologies (χ_m). In the early stages of development, when the distance from the technological level of the country to the global frontier is high, this is probably the most important dimension of productivity improvements. However, as the countries approach the world technological frontier

¹⁶ The frequency depends on the appropriate mix of policies and institutions (property rights, tax laws, competition policy, government services, level and composition of human capital, macroeconomic conditions or credit market constraints). However, as we have already mentioned, the appropriate institutions that enhance productivity growth in each moment depend on the distance of the country to the frontier of knowledge. See Aghion and Howitt (2006) and Acemoglu et al. (2006).

¹⁷ Expression (5) is the same as the one reported by Aghion and Howitt (2006), p. 275.

($A_t = A_t^f$), the second term in expression (5) becomes zero, and the only source of growth turns out to be the domestic capacity to bring out leading-edge innovations.¹⁸

Finally, by rearranging (5) and making use of (4), the growth rate of the economy will be expressed as:

$$g_t(Y) = \chi_n(\gamma - 1) + \chi_m \left(\frac{A_t^f}{A_t} - 1 \right) \quad (6)$$

Expression (6) shows that the growth rate of the economy depends on domestic conditions, as well as on the capacity to catch up on foreign technology, which in turn depends on the domestic absorptive capacity and on the ratio between the level of domestic and foreign productivity. And since, in this kind of models, the only way to increase the level of productivity is to put new intermediate and capital goods to use, the magnitude of this term is related to the composition of investment. Thus, like Lee (1995), in the empirical analysis we approach this effect by considering the ratio between imported and domestically produced intermediate and capital goods. But, unlike Lee, where developed and developing countries grow at the same rate in the long run and the growth rate of income in developing countries could be higher only in the transitional dynamics, in our analysis we stress that the composition of investment could also improve the rate of economic growth in the long run. And what is more important, in Lee's paper, the higher growth rate in the transitional dynamic path in the developing country is due to the effect of the ratio of imported to domestically produced intermediate and capital goods on the growth rate of capital stock (improving the efficiency of capital accumulation). Alternatively, in our analysis, we stress the role of foreign intermediate and capital goods as a source of long-run growth through other channels. The first of these channels is by improving the efficiency of domestic production processes due to technological progress embodied in these imported goods and the second is by accelerating technological catching-up through the domestic producers' processes of learning from foreign suppliers.

¹⁸ This suggests that during the growth process both strategies – indigenous and foreign innovation – should be complementary. See Fu et al. (2011).

3. The Empirical model

3.1 Data

As stated earlier, our main goal is to analyse the role played by the ratio of imported to domestically-produced capital goods in income growth. However, in order to find any robust effect of this ratio on the growth rate of the Chinese economy, it is necessary to control the estimates with additional policy variables, as suggested by Levine and Renelt (1992). Thus, in accordance with most of the empirical literature on growth, our data set includes the following variables: the growth rate of per capita income, $g(Y_{PC})$; the growth rate of the population, $g(N)$; the ratio of investment to GDP, (I/Y) ; the ratio of total imports to GDP, (M/Y) ; the ratio of government expenditure to GDP, (G/Y) ; the investment in human capital, $(\Delta H C)$, measured as the increases in the stock of human capital, approximated by per capita years of schooling; and the ratio of foreign capital to domestic capital goods, (FC/DC) . All variables are in constant prices except those that are ratios.¹⁹

The main data source was the National Bureau of Statistics of China (NBS). We used annual data covering the period 1965-2007. The turbulent period of the 1950s and the economic consequences of the Great Leap Forward have therefore been deliberately avoided, since they produce abnormal values and make it difficult to perform an empirical analysis.²⁰ Our key variable, FC/DC , was created following Hsu's (1989) and Lee's (1995) proposals. The starting point was to obtain the imported capital goods (FC) from Hsu (1989). Then, the data set built by this author was extended to cover the entire period of our analysis. Finally, the value of domestic capital goods (DC) was calculated by subtracting the value of imported capital goods (FC) from total investment, as in Lee (1995). The stock of human capital, in contrast, was taken from Wang and Yao (2003) and it was updated until 2007 with figures from NBS.²¹

¹⁹ We used the GDP deflator, 1952 base year.

²⁰ See Chow (1993).

²¹ See Wang and Yao (2003) for the details in the construction of human capital stock.

Finally, as we are examining the Chinese economy, we cannot ignore the scepticism that exists about the quality of the Chinese data. Yet, the NBS has made continuous efforts to revise the data and to provide more accurate information in compliance with the international standards on macroeconomic aggregates.²² This is especially true for the revision that took place in 2005, which is the compilation that we use in the present work. This data set is more accurate than those from previous publications and the data have been revised for the whole period. In addition, it is widely agreed that even though the data present some inaccuracies on certain levels, the long-run trends are approximately correct (Chow, 2004; Holz, 2005; Bai et al., 2006).

3.2 Specification issues and the VAR model approach

One of the main concerns with the aforementioned variables in the empirical analysis is the subject of potentially endogenous regressors. We deal with this issue by applying the VAR model proposed by Johansen (1988, 1995), Johansen and Juselius (1990) and Juselius (2007). This methodology takes into account the potential interdependence between the explanatory variables and economic growth, the main variables being considered endogenous at the outset in a joint estimation framework. This procedure prevents any spurious results coming from the endogeneity problem. Moreover, in the later stages of this method it makes it possible to distinguish between which variables are endogenous and which are weakly exogenous by carrying out weak exogeneity tests. Thus, the researcher does not impose any restrictions on the model and hence allows “*the data to speak freely*” (Hoover, Johansen and Juselius, 2008). Related to this, an additional advantage of this approach is that it is possible to test the direction of the causality of the variables in the model. Moreover, using cointegration techniques allows us to avoid any problems with the non-stationarity of the variables since, if they are cointegrated, the combination of them produced by the cointegration relationship is stationary. Finally, with this methodology it is possible to distinguish the long- and short-run effects.

²² See Chow (2006).

Notwithstanding these advantages, however, it does also raise some problems, especially those related with the trade-off between the power of the tests and the length of time series and the number of variables included.²³

Thus, in our empirical analysis we use the following specification of the unrestricted VAR model:

$$\Delta X_t = \alpha \beta' \begin{pmatrix} X \\ Z \\ t \\ D_s \end{pmatrix}_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \sum_{i=0}^{k-1} \phi_i \Delta Z_{t-i} + \sum_{i=0}^{k-1} \theta_i \Delta D_{st-i} + \gamma D_t + \mu + \varepsilon_t \quad (7)$$

$$\varepsilon_t \sim NIID(0, \Omega) \quad t = 1 \dots T$$

where X_t is a vector which contains the endogenous variables of the model, Z_t includes variables considered a priori as being weakly exogenous, t is the linear trend and D_s is a vector with two shift dummies (1967 and 1985) restricted to the cointegration space. α shows the direction and speed of adjustment to equilibrium, while β are the coefficients of the cointegrating vectors. For each of the elements described above, except for the deterministic trend, there is a dynamic representation in the model. In addition, we include a constant term (μ) and two additional permanent dummies, γD_t , in 1976 and 1989, to ensure the stability of long-term relationships. Both the constant term and the permanent dummies are unrestricted to the cointegration space. Finally, we assumed that the initial values X_{-k+1}, \dots, X_0 , are fixed.

The more than likely non-stationarity of the variables needs to be tested with the unit root tests, since combining them produces a stationary relation if they are cointegrated. Furthermore, the reliability of the estimations is guaranteed by performing a set of diagnostic tests on the residuals and the specification of the model is determined by the weak exogeneity test. Finally, the number of long-run cointegrating vectors is indicated by the rank of the long-run matrix in equation 7. Results of these tests are reported in Tables 1-4.

²³ With this methodology, the power of the test tends to be greater as the number of included variables becomes lower and the length of the time series considered increases in size. This leads us to be quite restrictive as regards the number of variables considered in the model.

Although the ADF and Phillips-Perron tests are the most commonly used methods to test for the presence of unit roots, many researchers remain sceptical about the results from these standard unit root tests. It is well known that ADF-type tests have lower power and might provide misleading results and that Perron tests may undergo severe size distortions when applied to unit root processes subject to structural changes.²⁴ Thus, in this paper, we use the unit root test with two (endogenously determined) structural breaks proposed by Lee and Strazicich (2003) that have a higher power to detect the unit roots than previous tests.²⁵

From Table 1A we can observe that the growth rate of per capita income is non-stationary and has a unit root, that is, it is integrated of order two in levels. This result of the non-stationarity of the growth rate of per capita income is more consistent with the endogenous models of growth than with the exogenous growth models.²⁶ The stock of human capital is also integrated of order two and hence we transformed this variable into first differences in order to apply the VAR model. The remaining variables, however, are integrated of order one in levels. This conclusion is corroborated with the information reported in Table 1B, where for the number of long-run relations selected, in accordance with the rank test that we will explain below, all our variables are non-stationary. Hence, if they are cointegrated, any combination of them will produce a stationary relationship.

Insert Tables 1A and 1B about here

Table 2 shows the battery of misspecification tests on the residuals of the unrestricted VAR model. It can also be observed how the model does not show any autocorrelation or normality problems and the R^2 is 0.94 for the equation of interest (per capita GDP growth rate). However,

²⁴ See Perron and Ng, 1996; Lee and Strazicich, 2001; Lanne et al., 2002; and Lanne and Lütkepohl, 2002.

²⁵ For further details, see Lee and Strazicich (2003). For a detailed discussion of the unit root tests and their link with growth models, see Herrerias and Orts (2011). The stationarity test is implemented in CATS in RATS, which is specific software for performing the VAR model.

²⁶ As stated by Jones (1995), one of the main arguments against endogenous growth is based on the stationarity of growth rates.

a small ARCH effect is detected in the multivariate analysis. Nevertheless, Rahbek et al. (2002) and Juselius (2007) suggested that the statistical inference, in particular the determination of the rank test, in the cointegrated VAR model, is robust to a moderate ARCH effect and that, overall, the model is well behaved. Finally, the determination of the number of lags, according to the criterion of Hannan and Quinn, indicates that two lags are enough to capture the effects of the dynamics of the model and to avoid autocorrelation problems.

Insert Table 2 about here

Once we have the well-specified model, we perform the weak exogeneity test and the rank test on the long-run matrix. Recall that we started the initial analysis by assuming that all variables were endogenous, as the methodology requires, but the researcher has to test this hypothesis through the weak exogeneity test. This division of the variables and the identification of the number of cointegrating vectors are performed almost simultaneously because the division between endogenous and weakly exogenous variables influences the rank test, and the weak exogeneity test is based on the result from the rank test. Thus, once the final specification is reached, we find that in this model the only endogenous variables are the growth rate of per capita income and the growth rate of population, the remaining variables being weakly exogenous (see Table 3).²⁷ The weak exogeneity of a particular variable implies that it has influenced the long-run stochastic path of other variables in the system, while at the same time remaining uninfluenced by them. This type of test helps us to answer questions of enormous importance in economic policy analysis, and hence to assist us in elucidating which variable could be used as a policy instrument or is really endogenous to the system. In essence, the answer depends on the direction of the causality among the variables of interest. We will come back to this issue in the next subsection.

²⁷ Weak exogeneity implies that the variable examined has a zero row in α in equation (1).

Insert Tables 3 and 4 about here

Finally, we can test the number of long-run relationships (r) and common trends ($p - r$) by the LR test. The results are reported in Table 4. The procedure begins by investigating the first null hypothesis, that is, the absence of cointegration ($r = 0$) and if it is rejected, we go on to examine the next hypothesis $r = 1$, which posits that in this model a cointegrating relationship exists. Table 4 shows that in the latter it is not possible to reject the null due to the fact that the p -value is 0.3. However, it is well known that the determination of the rank test requires additional information such as the root of companion matrix, the graphics of the long-run relations, the alpha coefficients from the long-run matrix, and so forth. Thus, to confirm our suspicion that there seems to be only a long-run relationship, we provide additional information for the analysis, such as that coming from the root of companion matrix.²⁸ From there, it is possible to observe that, the inverse root of the characteristic polynomial is less than unity and with a small value (0.635), thereby showing that in our model only one long-run relationship exists.²⁹

3.3 Empirical results

Non-stationary data raises two different identification problems, namely: identification of the long-run structure (i.e. of the cointegration relations) and identification of the short-run structure (i.e. of the equations of the system). The former refers to imposing the long-run economic structure on the unrestricted cointegration relations, while the latter is about imposing the short-run dynamic adjustment structure on the equations for the differentiated process. The process is carried out in two steps due to the difficulties involved in the estimation. To simplify the

²⁸ The other information is not reported here to save space in the paper, but is available from the authors upon request.

²⁹ See Juselius (2007) for further technical details about the identification of the number of cointegrating vectors.

analysis, the identification process starts by identifying β in the reduced form and then goes on to identify the short-run structure while keeping the identified β fixed.³⁰

The identification of the long-run structure requires the imposition of restrictions on the cointegrating relation that we found. The concentrated model R_i (the long-run relations) denotes a $p1 \times m_i$ restriction matrix and $H_i = R_i \perp$ a $p1 \times s_i$ design matrix ($m_i + s_i = p1$) so that H_i is defined by $R_i' H_i = 0$. Thus, there are m_i restrictions and consequently s_i parameters to be estimated in the i -th relation. The cointegrating relations are assumed to satisfy the restrictions $R_i' \beta_i = 0$ or equivalently $\beta_i = (H_i \phi_i)$ for some s_i -vector ϕ_i , that is:

$$\beta = (H_1 \phi_1, \dots, H_r \phi_r),$$

where the matrices H_1, \dots, H_r , express linear hypotheses to be tested against the data. For the researcher to formulate the hypothesis of interest, the first step is to examine the structure defined by $\beta = (H_1 \phi_1, \dots, H_r \phi_r)$. In our case, the general specification for the cointegrating relation found through the application of the LR test is as follows:³¹

$$\beta' \begin{pmatrix} X \\ Z \end{pmatrix}_{t-1} = \tag{8}$$

$$= \beta_{11} g_t(Y_{PC}) + \beta_{12} g_t(N)_t + \beta_{13} (I/Y)_t + \beta_{14} \Delta HC_t + \beta_{15} (FC/DC)_t + \beta_{16} (M/Y)_t + \beta_{17} (G/Y)_t$$

and after normalizing the cointegrating vector found on $g(Y_{PC})$, we have:³²

$$\beta' / \beta_{11} \begin{pmatrix} X \\ Z \end{pmatrix}_{t-1} =$$

$$= g_t(Y_{PC}) + \beta_{12} / \beta_{11} g_t(N)_t + \beta_{13} / \beta_{11} (I/Y)_t + \beta_{14} / \beta_{11} \Delta HC_t +$$

$$+ \beta_{15} / \beta_{11} (FC/DC)_t + \beta_{16} / \beta_{11} (M/Y)_t + \beta_{17} / \beta_{11} (G/Y)_t$$

³⁰ For all aspects regarding the identification, see Johansen and Juselius (1994).

³¹ For the sake of simplicity, in (8) we have omitted the deterministic components of the long-run relationship.

³² When we normalized β_i by dividing through with a non-zero element β_{ij} , the corresponding α_i vector is multiplied by the same element. Thus, normalization does not change $\Pi = \alpha_i \beta_i = \alpha \beta'$ and we can choose whether to normalize or not. However, when the long-run structure is identified, normalization becomes more important. This is because it is only possible to obtain standard errors of $\hat{\beta}_{ij}$ when each cointegration vector is properly normalized (Juselius, 2007).

Now we have the theoretical and the empirical framework for testing the predictions we are interested in. For instance, we can test whether capital accumulation (physical and human capital) has a long-run effect on the growth rate of the Chinese economy. This hypothesis is consistent with the AK-models developed by Romer (1986), Lucas (1988) and Rebelo (1991), as well as the subsequent generation of endogenous growth models developed by Romer (1990), Grossman and Helpman (1991b) or Aghion and Howitt (1992). These models suggested that investment, defined in a broad sense, has permanent effects on the growth rate of the economy. This hypothesis can also be formulated imposing the condition that $\beta_{13}/\beta_{11} = \beta_{14}/\beta_{11} = 0$, which implies that the restriction takes the form of (1, 1, 0, 0, 1, 1, 1). However, this hypothesis was rejected by the data with a *p-value* of 0.033. Hence, the first important conclusion is that capital accumulation (understood in a broad sense, that is, including physical and human capital) *matters* for long-run economic growth in China. The second hypothesis that we can formulate concerns whether Chinese growth is higher using more foreign capital *relative* to domestic capital goods. Analogously, it implies that $\beta_{15}/\beta_{11} = 0$ and the restriction takes the form of (1, 1, 1, 1, 0, 1, 1). The results indicate that the use of higher foreign capital relative to domestic capital has influenced long-run growth in the Chinese economy, since this hypothesis is rejected with a *p-value* of 0.000. However, our model also includes the ratio of total imports to GDP. As Lee (1995) argued, if foreign trade affects growth through the importation of capital goods, the usual trade indicators such as exports to GDP or imports to GDP are not accurate measures for investigating the causal relation between trade and growth. This idea can be tested with the Chinese data. It implies that $\beta_{16}/\beta_{11} = 0$ and the restriction becomes (1, 1, 1, 1, 1, 0, 1). The results indicate that the main channel for encouraging economic growth in China is the importation of foreign capital goods. This is because we cannot reject the fact that the ratio of imports to GDP is different from zero (*p-value* of 0.491). This result is quite reasonable because China's economy does not have a comparative advantage in the production of technologically advanced capital goods. Therefore, through international trade it can import those goods so that

the production process can benefit from the lower relative price and hence be an important mechanism to stimulate productivity and growth.

By eliminating the non-significant coefficients of the long-run relationship in this model, we can obtain the economic relation that was identified (t-statistic in brackets), that is:

$$g(Y_{PC}) = 5.02g(N) + 0.54(I/Y) + 0.09\Delta HC + 1.01(FC/DC) - 0.418(G/Y) - 0.08D_{s67}$$

[4.18] [4.70] [4.08] [5.97] [-5.01] [-7.06]

(9)

In the above equation we can see that all coefficients show the expected sign and are significant. The coefficient of adjustment in the long-run matrix towards equilibrium is negative and takes a value of -1.35 with a *t-statistic* of -15.62, thereby indicating that this economic relation is stationary. Moreover, we performed a set of tests to check the stability of the parameters and the results indicated that the coefficients were reasonably stable.³³ The restrictions imposed were accepted by the data with a *p-value* of 0.483. Our results suggest that the direction of the causality is unidirectional and runs from the ratio of foreign to domestic capital, population growth, physical and human capital accumulation and government expenditure to per capita GDP growth rate. This implies that China's growth is caused by the aforementioned factors and not by the possible reverse causation. Additionally, we found that the failure of the Great Leap Forward and the Cultural Revolution, which may be captured by the shift dummy in 1967 negatively influence the growth rate of income in China.

These results are consistent with the hypothesis that China's growth experience over the analysed period has followed an "investment-based strategy", in which the process of catching up with the world technological frontier has played a significant role. Thus, in line with the arguments proposed by Rodrik (1995) to explain the experience of the East Asian countries in the 1960s, investment and imports appear to have played a central role in the rapid growth undergone by the Chinese economy in the last few decades. However, in agreement with the Schumpeterian theory of growth outlined in section 2 – especially the versions developed by

³³ The set of stability tests are available from the authors upon request.

Acemoglu et al. (2006) and Aghion and Howitt (2006) – our results also indicate that investment composition has played a noteworthy role. In fact, besides the role played by capital accumulation, it can be seen that an increase in the proportion of imported capital goods over those produced domestically is accompanied by a higher rate of growth in China. This result is consistent with the empirical evidence that foreign capital, which usually has embodied technological progress from advanced countries, has been a central source of technological progress in developing countries.

Finally, our results also indicate that the most important channel through which openness to trade has enhanced growth is probably having access to technologically advanced capital goods from more developed countries and not the increase in trade volume.

On the other hand, as already stated, the identification of the short-run structure is greatly facilitated by keeping the properly identified cointegrating relations fixed at their estimated values.³⁴ Similar to the previous process, the short-run structure is identified by imposing a restriction equal to zero on the non-significant coefficients until the most irreducible form is reached. The results are reported in Table 5, where the restrictions were accepted by the data with a *p-value* of 0.0782.

Insert Table 5 about here

Not surprisingly, the short-run effects are scarce in this model because our key determinants are more consistent with long-run effects. The most important feature of the dynamics of the model estimated is that reported by the parameters of the error correction mechanism (ECM), that is, the long-run relation expressed as a deviation away from the steady state. The table above shows that the acceleration of the growth rate is error correcting with the cointegrating relation specified in (9), due to the negative coefficient of the ECM. On the other hand, the

³⁴ The statistical justification is that the estimates of the long-run parameters $\hat{\beta}$ are superconsistent, i.e. the speed of convergence towards the true value β is proportional to T as $T \rightarrow \infty$, whereas the convergence of the estimates of the short-run adjustment parameters is proportional to \sqrt{T} .

coefficient of the ECM in the other equation, $\Delta g(N)$, implies that improvements in the growth rate of income in the Chinese economy stimulate the rate at which China's population grows.³⁵ An interesting result is that human capital and investment influence the rate of growth of income in both the short and the long run in China.

Insert Figure 2 about here

Finally, to conclude the empirical analysis, we provide additional information in order to enrich the results, but in the short-run (as appears in Figure 2, which shows the response of the growth rate of per capita GDP when there is an innovation in the ratio of foreign capital relative to domestic capital, investment shares and human capital). The results mainly confirm the previous analyses in the sense that these three factors are relevant for the Chinese economy to encourage the rate of growth.

4. Conclusions and Policy Implications

This paper reports an empirical study of the joint determinants of long-run growth rate of per capita GDP in China from 1965 to 2007. We have focused on the role played by capital accumulation and openness in this process and used the VAR model to find the long-run cointegrated relationships.

The main finding was that the rate of capital accumulation and the relative proportion of foreign over domestic capital goods used in the local production processes were directly related to the Chinese per capita GDP growth rate, over the period under consideration. These results are consistent with the hypothesis that the link between trade openness and long-run growth worked mainly through imports, and especially through the importation of capital goods. These imports allow for two types of benefits: first, they improve the efficiency of capital accumulation and, second, they become a source of technological catching-up. The first effect is the result of exploiting the comparative advantage through the importation of cheaper capital

³⁵ It is not the aim of this paper to examine the determinants of the growth rate of the population.

goods from more developed countries. The second, however, is due to technological progress embodied in the imported capital goods, which allow foreign technology to be incorporated into the productive activity, thus increasing the efficiency of domestic production and innovation processes. In short, the investment effort, together with the efficiency of capital accumulation and the composition of investment, have been key aspects in accounting for China's growth in the last four decades.

Furthermore, this evidence is in agreement with the point of view stressed by authors such as Acemoglu et al. (2006) or Aghion and Howitt (2006), who suggest that in the early stages of growth, government intervention to encourage an "investment-based strategy" (which emphasizes large investment efforts and the adoption of foreign technology) might be appropriate to successfully enhance productivity and output growth. And this is true even if this strategy has to be played at the expenses of some non-competitive arrangements or market rigidities. However, the same theoretical framework that allows us to articulate the above results also draws attention to the need to gradually replace the aforementioned anticompetitive practices by a more competitive environment which encourages leading-edge or local innovation. This change from an investment-based to an innovation-based strategy is essential to sustain growth and convergence as the economy achieves higher levels of development and approaches the technological frontier.³⁶ Nevertheless, there is an inherent difficulty in switching to the innovation-based strategy. Groups that have benefited from the investment-based policy, and have gained economic power in this period, will strongly oppose a change in the growth strategy that harms their economic power, thereby hindering the necessary switch.

Finally, although these results apparently disagree with the export-led growth literature (and to some extent this is true), export promotion could have been a central piece of this policy, thus preventing the external constraint of the economy to stop this development strategy. Of course, our claim is that the main beneficial source of openness to growth came from imports and

³⁶ This change must be gradual and occur at a different pace in each sector, depending of the magnitude of the technological gap in each case. In this sense, recent evidence seems to confirm that this is the case of China. See Fu and Gong (2011).

specifically from their capacity to improve the composition of investment. But this is consistent with the observed strong Chinese export orientation, if we think that the export competitiveness of China could be supported, at least partially, by imported technology as a source from which to develop the local technological capabilities.

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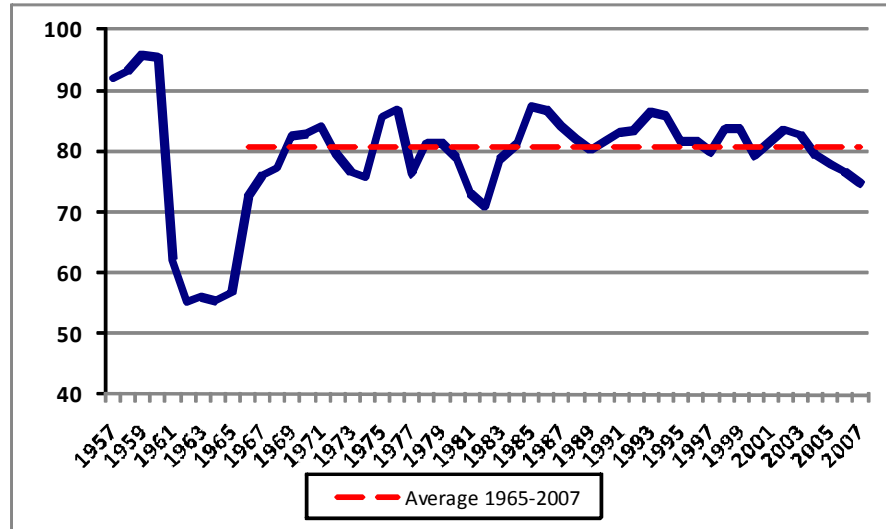
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Figure 1: Share of Imported Capital Goods over Total Imports (1957-2007)



Source: National Bureau of Statistics of China.

Table 1A: Lee and Strazicich unit root tests (two structural breaks)

Levels	2 breaks	Statistic	Differences	2 breaks	Statistic
$g(Y_{PC})$	1977 2002	-5.77	$\Delta g(Y_{PC})$	1979 2004	-10.85*
I/Y	1987 2004	-4.91	$\Delta(I/Y)$	1988 1999	-5.94*
M/Y	1984 2001	-5.77	$\Delta(M/Y)$	1993 2000	-6.94*
G/Y	1978 1997	-5.09	$\Delta(G/Y)$	1990 2001	-5.86**
FC/DC	1985 1997	-5.61	$\Delta(FC/DC)$	1980 1990	-11.3*
HC	1983 1998	-5.23	ΔHC	1986 1999	-6.18

Note: * indicates the rejection of the null hypothesis at the 1% level of significance, ** at 5%. See Lee and Strazicich (2003) for the critical values.

Table 1B: Stationarity Test

R	DGF	$g(Y_{PC})$	$g(N)$	G/Y	FC/DC	M/Y	I/Y
$\rightarrow 1 \leftarrow$	7	22.181 [0.002]	71.144 [0.000]	68.519 [0.000]	75.278 [0.000]	71.544 [0.000]	60.823 [0.000]
2	6	16.855 [0.010]	42.272 [0.000]	39.294 [0.000]	46.299 [0.000]	42.315 [0.000]	32.577 [0.000]
3	5	11.87 [0.037]	27.174 [0.000]	31.046 [0.000]	29.623 [0.000]	28.625 [0.000]	22.602 [0.000]
4	4	13.747 [0.008]	9.53 [0.049]	13.223 [0.010]	17.941 [0.001]	15.034 [0.005]	7.782 [0.100]
5	3	7.483 [0.058]	2.727 [0.436]	3.094 [0.377]	5.441 [0.142]	8.353 [0.039]	2.548 [0.467]

Note: p-values in brackets. The statistic denotes the rejection of the null hypothesis of stationarity

Table 2: Residual Analysis

Test for Autocorrelation			
LM(1):	$\chi^2(4)$	2.434	[0.656]
LM(2):	$\chi^2(4)$	2.992	[0.559]
Test for Normality			
	$\chi^2(4)$	7.924	[0.094]
Test for ARCH			
LM(1):	$\chi^2(9)$	11.768	[0.227]
LM(2):	$\chi^2(18)$	31.841	[0.023]

Table 3: Test of long-run weak exogeneity³⁷

R	DGF	$g(Y_{PC})$	$g(N)$	G/Y	FC/DC	M/Y	I/Y
$\rightarrow \mathbf{1} \leftarrow$	1	29.227 [0.000]	3.628 [0.057]	0.31 [0.578]	0.68 [0.410]	1.416 [0.234]	2.435 [0.119]
2	2	49.406 [0.000]	5.42 [0.067]	0.615 [0.735]	1.388 [0.500]	15.242 [0.000]	18.719 [0.000]
3	3	65.728 [0.000]	8.926 [0.030]	12.533 [0.006]	9.727 [0.021]	20.162 [0.000]	32.378 [0.000]
4	4	69.247 [0.000]	12.646 [0.013]	12.534 [0.014]	19.792 [0.001]	20.781 [0.000]	32.378 [0.000]
5	5	74.615 [0.000]	12.646 [0.027]	16.849 [0.005]	25.564 [0.000]	25.596 [0.000]	39.388 [0.000]

Table 4: The rank test and root of companion matrix

$p-r$	r	Eig.Value	Trace	Trace*	P-Value	P-Value*
2	0	0.867	110.799	105.136	0.000	0.000
1	1	0.396	22.179	21.866	0.301	$\rightarrow \mathbf{0.318} \leftarrow$
			H(0)	H(1)	H(2)	
Modulus						
Root1	1		1		0.745	
Root2	1		0.635		0.671	
Root3	0.513		0.635		0.671	
Root4	0.07		0.477		0.611	

³⁷ Although the p-value of the growth rate of the population is slightly over 0.05, we have allowed it to be endogenous. In fact, we can check it in the dynamics of the model, where its coefficient of ecm is significant, thus implying that this variable is endogenous in this model.

Table 5: Short-run identification

	$\Delta g(Y_{PC})_t$	$\Delta g(N)_t$
$\Delta^2 HC_t$	0.16 (10.7)	-
$\Delta I/Y_t$	1.15 (6.70)	-
$\Delta I/Y_{t-1}$	-	-0.017 (-1.90)
$\Delta G/Y_{t-1}$	-	-0.042 (-4.14)
$\Delta FC/DC_t$	-	-0.08 (-4.99)
ECM_{t-1}	-3.59 (-5.40)	0.21 (5.64)

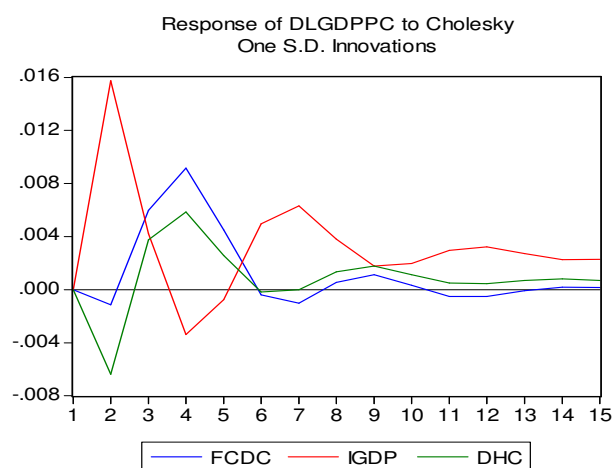


Figure 2: Response of $g(Y_{PC})$ to Cholesky one S.D. innovations in FC/DC, I/Y and ΔHC