The Driving Forces behind China's Growth *

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Abstract

The main objective of this paper is to disentangling the determinants of the Chinese economic growth that occurred from 1965 to 2000. We have explored, first, the time series properties of the growth rates of GDP and labour productivity with an extended battery of unit root tests. Then, in a multivariate setting, we use the VAR model methodology to provide evidence that physical and human capital accumulation, R&D expenditure, openness and competitiveness are the main drivers of output, labour productivity and total factor productivity growth in the long run. Additionally, we also show that although China has not yet converged to its long-run equilibrium, it is in the process of catching up. These results are more consistent with some versions of the endogenous growth models than with Solow-type models of growth, since they support active strategies of economic policy to stimulate economic growth and catching up with more advanced economies.

Key words: China, Capital accumulation, R&D, Openness, Growth

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1. Introduction

As stated by Jones (1995), the early AK-style models developed by Romer (1986), Lucas (1988) and Rebelo (1991), as well as the subsequent models of growth based on endogenous technical change such as those by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), suggested that investment, defined in a broad sense, has permanent effects on the growth rate of the economy and can also improve the long-run path of productivity growth through learning-by-doing and technology spillovers. However, this relationship between investment and growth has become one of the most controversial issues in the empirical literature. Thus, Jones (1995) did not find evidence of permanent effects of investment on economic growth, a result which rejected the main implications of endogenous growth models and supported Solow's view of growth. Furthermore, Bloström et al. (1996) found that the strong relationship between investment shares of GDP and growth were due more to the effect of growth on capital formation than to the effect of capital formation on growth. These findings have led to doubts about the validity of such models as an alternative to the Solow framework and therefore the relationship between investment and other policy variables and growth. This issue has since been reviewed several times in the literature from both a theoretical and an empirical point of view. From a theoretical perspective, the Schumpeterian version of the endogenous growth theory, developed by Howitt and Aghion (1998) among others, stands out above the rest. In this approach, capital accumulation, due to embodied technological progress, and innovation activities determine the rate of growth and have permanent effects on the rate of productivity growth. Similarly, and from an empirical point of view, using more sophisticated econometric techniques, some authors have recently found evidence of a positive relationship between investment and growth (Bernanke and Gürkaynak, 2001; Li, 2002; Bond et al., 2004).

In this context, the Chinese economy, which has been characterized by high growth rates for almost four decades and high rates of capital accumulation, represents an interesting case with which to analyse this relationship. Additionally, testing for the existence of a long-term relationship between the two magnitudes, together with other relevant sources of growth emphasized by endogenous growth models, can help us to discriminate between the driving forces behind China's growth. At the same time, it could be useful to clarify whether it has only been the result of a process of factor accumulation or if, on the contrary, this factor accumulation has co-existed with significant technological or efficiency gains. From this perspective, some authors such as Chow (1993) and Woo (1998) argued that the rapid growth of China is mainly due to the injection of productive factors, without technological progress playing any significant role. These authors consider that the pattern of growth of China is similar to that experienced by East Asian countries in the sixties. In those cases, economic growth was stimulated mainly by capital accumulation and, consequently, the high rates initially displayed by these economies turn into "normal rates" after a period of time and have just a transitory effect on the growth rate (Krugman, 1994; Young, 1995).

However, from the perspective of the endogenous growth models, the influence of the accumulation of capital, along with other additional elements such as openness, innovation activities, investment in human capital and so on, are capable of generating sustained efficiency gains and growth in the long run. The debate is interesting, both from the standpoint of analysing the nature (permanent or transitory) of the effects of these factors on the growth rate of output and productivity, and from their implications for the sustainability of growth and for the design of appropriate economic policies. For instance, should China pursue outward- or inward-oriented policies? Has capital accumulation been a suitable strategy to sustain high growth rates? Do innovation activities influence the long-run rate of economic growth? Could competitive exchange rates and other government policies promote growth in the long run? If this is the case, is there a causal relationship among these determinants and economic growth?

To address these questions, economists have focused on diverse theoretical frameworks and have used different empirical methodologies, with very mixed results. As a consequence the sources and nature of Chinese growth remain an open question. This study attempts to make a contribution in this strand of the literature. In particular, the purpose of this paper is to analyse the link between investment and long-run growth of output and productivity,[1] and their interactions with other sources of economic growth like openness to trade, R&D expenditure, human capital and competitiveness in China from 1965 to 2000. Thus, in our empirical analysis we have two complementary focal points of interest. First, we analyse the statistical properties of productivity and output growth series with an extended battery of unit root tests. We begin by re-examining this issue because it has relevant

[1] Although the study of the growth of GDP per capita is more relevant from a welfare perspective, growth theory focuses mainly on the productive capacity of countries, making it "therefore easier to map to data when we look at output (GDP) per worker". Acemoglu (2009), p. 6.

implications in both the inference in time series analysis and in economic growth analysis. In fact, one of the main arguments against endogenous growth is based on the stationarity of growth rates.[2] And second, in order to avoid the main modelling problems in time series analysis (stochastic trends in the variables and potentially endogenous regressors) and given the established links between cointegration and endogenous growth models,[3] we use the cointegrated VAR methodology to analyse the short- and long-run relationships among the different potential determinants of output and productivity growth rates. In addition, since we know that China's economy has been immersed within a set of continuous shocks and transformations, we have introduced different structural breaks, which allow us to guarantee the stability of our long-run relations. The econometric results provide robust evidence that capital accumulation, in a broad sense (physical and human capital), innovation activities (R&D), and openness to trade (exports and imports) have been the main factors which determine the long-run growth rate of output and productivity (both labour and total factor productivity) in China. Furthermore, we found some evidence that the sustained high real exchange rate also played a significant role in explaining the growth of output and labour productivity in the period considered. Thus, these results are more consistent with some versions of the endogenous growth theory than with Solow's model of growth.

Finally, and continuing with the time series analysis, we examine whether the Chinese economy is catching up with or converging to one of the most advanced economies in the world (USA). The empirical evidence implies that, although China has not yet converged, it is in a process of catching-up, i.e. of narrowing the (log output per worker) gap with other more advanced economies.

The rest of the paper is set out as follows. In Section 2 we present a literature overview and outline a theoretical model to illustrate our empirical analysis. Section 3 offers a description of the variables that were considered, the strategy of the empirical analysis and model specification, as well as the main empirical results. In Section 4, we test for catching-up and convergence and, finally, section 5 includes the conclusions that were drawn.

2. An Overview of the Literature

One aspect that is common to all the theoretical literature on economic growth, from the Solow textbook model to the more recent endogenous models developed by Romer (1986, 1990), Lucas

[2] See for example Jones (1995) or Kocherlakota and Yi (1997).
[3] See for example Lau and Sin (1997) and Lau (1999).

(1988), Grossman and Helpman (1991), Rebelo (1991), Aghion and Howitt (1992) or Howitt and Aghion (1998) among others, has been to highlight the contribution of the accumulation of productive factors, especially physical and human capital, and technological progress in explaining economic growth. In this literature, capital accumulation has played a central role and these developments have logically been reflected in the aims of empirical work. Thus, a lot of empirical literature has focused on the effect of capital accumulation on growth, but with mixed results. While the aforementioned papers by Jones (1995) or Bloström et al. (1996), among others, do not find evidence of permanent effects of investment on economic growth, in more recent contributions by Bernanke and Gürkaynak (2001), Li (2002) or Bond et al. (2004), some evidence of a positive relationship between investment and growth does seem to emerge. Similarly, and in addition to physical capital, human capital has also been considered a fundamental factor in determining long-run growth rate in the literature (Lucas, 1988; Barro, 2001). More highly skilled workers could facilitate the introduction of larger amounts of new, better quality varieties of intermediate goods and could increase the productivity of physical capital through specialization and by improving the learning-by-doing mechanism, thus raising efficiency and productivity. In addition, education acts as a factor of production, either directly by stimulating the development of new technologies or through facilitating technology use, adaptation or imitation, thereby avoiding the threshold limitation that human capital imposes on the technological absorptive capability of developing countries (Borensztein et al., 1998; Bils and Klenow, 2000; Benhabib and Spiegel, 2005). Finally, there are externalities associated with better-educated people that can positively affect long-run growth rates (Sianesi and Reenen, 2003).

However, one of the main issues on which some discrepancy persists in this field is whether these factors can or cannot have permanent effects on growth in the long run. This controversy is easily illustrated with a standard growth model. Consider the following human capital augmented Solow-type model: the production function with constant returns to scale and decreasing returns to reproducible factors can be written as:

$$Y_t = K_t^{\alpha} H_t^{\beta} \left(A_t L_t\right)^{1-\alpha-\beta}$$

where Y is output, K and H are physical and human capital respectively, L is labour and A is labour augmenting technological progress, and $0 < \alpha + \beta < 1$. This production function can be expressed in intensive terms as:

$$y_t = k_t^{\alpha} h_t^{\beta} \qquad (1)$$

where *y, k and h* are the output level and the stocks of physical and human capital expressed in intensive terms, that is, *y =Y/AL*, *k =K/AL* and *h =H/AL*. From (1) it is clear that, as a whole, the production function under consideration exhibits decreasing returns to capital.

Assuming that i_k an i_h, are the constant investment rates in physical and human capital, that both types of capital depreciate at the common rate δ, and that *L* and *A* grow exogenously at rates *n* and *a* respectively, the time paths of the variables involved in (1) are given by:

$$\dot{k} = i_k y - (a + n + \delta)k \qquad (2)$$

$$\dot{h} = i_h y - (a + n + \delta)h \qquad (3)$$

$$\dot{\mathrm{A}} = a\mathrm{A} \qquad (4)$$

$$\dot{\mathrm{L}} = n\mathrm{L} \qquad (5)$$

Given the existence of decreasing returns on reproducible factors, the long-run steady state of the model can be found by solving (1) to (5) for $\dot{k} = \dot{h}$ =0, so that:

$$k = \left(\frac{i_h^{\beta}\ i_k^{1-\beta}}{a + n + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \qquad (6)$$

$$h = \frac{i_h}{i_k} k \qquad (7)$$

$$y = \frac{a + n + \delta}{i_k} k \qquad (8)$$

Expressions (6) to (8) define the constant steady-state level of physical capital stock, human capital and output per worker in intensive terms. From these expressions it is straightforward to see the standard textbook result of Solow-type growth models, which is that in the steady state the growth rate of output per worker (*g*) is determined by the rate of exogenous technological progress (*a*), without any influence of structural parameters such as investment rates; that is:

$$g = a \qquad (9)$$

The empirical implication of (9), in Jones's (1995) words, is that the "level of output is fit well by a growth process with a constant mean … and very little persistence".[4] This implication is in sharp contrast with the empirical implications of the endogenous growth models. According to these models, first, *a* does not have to be exogenous or necessarily characterized by a process with a constant mean and very little persistence and, second, the long-run dynamics of *a* will be determined by the dynamics of the different factors which could generate sustained efficiency gains in the long run.

Consider, for example, that in the preceding model $\beta = 1-\alpha$; in this context the model exhibits constant returns to capital as a whole (AK model), and this is enough to generate endogenous growth. Solving the model again, it is easy to see that the relationship between *h* and *k* remains constant and equal to $(1-\alpha)/\alpha$, and *y* can be expressed as just a function of *k* or *h*:

$$y_t = \left(\frac{1-\alpha}{\alpha}\right)^{(1-\alpha)} k_t$$

Now, however, *h* and *k* do not remain constant in the long-run steady state, instead they just grow at the same rate. Consequently, the steady state cannot be established in terms of the variables in levels but in growth rates; and the steady-state growth rate of output per worker can be expressed as a function of physical or human capital accumulation, that is:

$$g_t = a + \Delta k_t / k_t \qquad (10)$$

Thus, the AK endogenous growth models stressed the link between capital accumulation, in a broad sense, and growth,[5] in opposition to the point of view of Solow-type models, where the main driver of steady-state economic growth is just the exogenous technological progress. Alternatively, the endogenous technological change models developed by Romer (1990), Grossman and Helpman (1991) or Aghion and Howitt (1992), among others, emphasized the contribution of innovation activities to economic growth. In contrast, the Schumpeterian version of endogenous growth, developed by Aghion and Howitt (1998) among others,[6] extended the preceding models to integrate both determinants and stressed the complementarities between physical and human capital accumulation and technological change as the main mechanism driving growth performance and

[4] Jones (1995), pp. 498-499.
[5] Given the relationship between *h* and *k*, we could also express the growth rate of output per worker in terms of per capita human capital growth, that is, $g_t = a + \Delta k_t / k_t \equiv a + \Delta h_t / h_t$.
[6] Howitt and Aghion (1998) review the endogenous literature from this perspective.

permanent increases in the growth of productivity. In sum, as stated by Jones (1995): "a hallmark of the endogenous growth literature is that permanent changes in variables that are potentially affected by government policy lead to permanent changes in the growth rates".[7]

It is also clear that the new growth theory grants other factors an important role as determinants of the steady-state growth rates. From our point of view, openness is among the most extensively addressed topics in economic growth and development and is a key factor in the recent development of the Chinese economy. There is growing agreement that both trade policies and higher trade volumes to GDP ratios are positively correlated with growth, even after controlling for a variety of other factors of growth (Wacziarg, 2001).[8] Openness to international trade is associated with different international research and development spillovers that positively affect long-run growth (Coe and Helpman, 1995). From the point of view of developing countries, openness to international trade offers attractive chances to acquire capital goods from abroad. These goods are often imported by developing countries from technologically advanced countries, thus facilitating the access of developing countries to relatively cheaper and technologically intensive capital goods (Lee, 1995; Mazumdar, 2001; Eaton and Kortum, 2001).[9] Moreover, the effort made in innovation based on imported technologies can be a precursor to the development of domestic innovation capabilities (Mody and Yilmaz, 2002). Finally, access to intermediate inputs, as regards both quantity and variety, is an additional mechanism to enhance long-run growth, since it affords domestic producers greater access to new innovations or imitations of new products (Grossman and Helpman, 1991; Broda and Weinstein, 2004).

In a similar way, exports are also considered to be a source of positive spillovers and efficiency gains. At first, the self-selection of firms that induces openness to trade improves the economy's productivity (Melitz, 2003). Export activity can, however, further increase the relative productivity of exporting firms compared with that of businesses which only operate in the domestic market. This is due to the learning process associated with the acquisition of different types of knowledge from their international contacts (new methods of production and organizational style, better product

[7] Jones (1995), p. 495.
[8] But growing consensus it is not the same as unanimity, and there are also some critics to this view. Thus, some author like Rodrik (1995 and 1999) or Rodriguez and Rodrik (2001), among others, observed that countries whose incomes are high for reasons other than trade may also trade more.
[9] A recent review of the literature showed that the positive effects of trade liberalization can be found in Baldwin (2003) and Greenaway and Kneller (2007).

designs, and so on) (Chuang, 1998; Clerides et al., 1998). This may also be due to the exploitation of the economies of scale that access to international trade allows (Helpman and Krugman, 1985). Moreover, exporting activity allows foreign exchange constraints to be relaxed, thus permitting increased imports of capital and intermediate goods (Esfahani, 1991; Riezman et al., 1996).

Additionally, in an open economy there is a close relationship between trade, investment, and economic development. There is empirical evidence to suggest that the effects of openness to international trade on economic growth are mediated largely by the rate of physical capital investment (Levine and Renelt, 1992; Baldwin and Seghezza, 1996; Wacziarg, 2001). An alternative point of view is to be found in Rodrik (1995), who suggests that exports, in the case of East Asian countries for example, may have been driven by an increase in the profitability of investment, with outward-oriented policies being a consequence of the investment boom rather than its instigator. Finally, and especially for developing countries, there is another factor that could influence the relationship between outward orientation and economic growth, i.e. the level of real exchange rate. Although the empirical evidence on the issue is also mixed and there is a significant body of empirical work which does not support the positive relationship between a sustained competitive currency and growth (Easterly, 2005; Acemoglu et al., 2003), in two recent papers by Gala (2007) and Rodrik (2008) evidence is provided to show that undervalued currencies (higher real exchange rates) stimulate growth. Specifically, Gala (2007) shows that maintaining a competitive exchange rate has been a key factor in most successful growth strategies in East and Southeast Asia in the last 30 years. Rodrik (2008), on the other hand, extends this evidence to a significant panel of developing countries, the channel through which this effect operates being the size of the tradable sector (especially industry).

In the case of China, economists have used different empirical methodologies and data at different levels of aggregation to address these issues. For example, some papers have used stochastic frontier production function approaches and non-parametric techniques at the national, provincial or industry level to assess the contribution of productive factors, improvements in efficiency and technological progress on productivity (Wu, 2000; Chen, 2003; Zheng et al., 2008, among others). Although these studies conclude that physical capital accumulation and technological progress have played a significant role in the post-reform period in China, they cannot distinguish what factors are responsible for the efficiency gains. In several different studies in which traditional econometric methods were employed, Chow (Chow, 1993; Chow and Lin, 2002; Chow, 2008) found that technological progress was absent during the pre-reform period, and total factor productivity (proxied by a deterministic linear trend) only increased sharply during the post-reform period. However, questions such as the non-stationarity of the variables, endogeneity and the direction of the causality between the potential determinants of China's growth are not considered, and the researcher relies on an exogenous growth framework.

Few empirical efforts have been made to simultaneously consider the aforementioned questions, which are especially relevant in time series analysis. Nevertheless, there are some exceptions. For example, Yu (1998) employed the Engle and Granger two-step estimator, over the period 1980 to 1990, and found that exports and investment explained output growth, while imports did not contribute to economic performance. In a time series approach using data from 1952 to 1993, Kwan et al. (1999) estimated equation by equation and found empirical evidence on the contribution of investment and exports to growth, exports being consistent with large increases in investment. In contrast, Qin et al. (2005) estimated a VAR model for the period 1993-2003, finding empirical evidence that the causation runs from output to investment. However, none of these authors consider the importance of human capital or innovation activities, or the potential interdependence between economic growth and its determinants, which suggests a joint modelling with the possibility of multiple cointegrating relations. Only the last work considers the endogeneity of investment, but in a bivariate analysis which could give rise to bias due to the omission of other relevant variables. On the other hand, Liu et al. (1997 and 2002), Jin (2004) and Yao (2006) find a positive relationship between exports and growth, while Fu (2005) argued that no evidence was found to suggest significant productivity gains at industrial level as a result of expanding exports. Finally, Hsiao and Hsiao (2006), using different empirical specifications, found that exports do not cause growth at all.[10] Thus, the empirical evidence between growth, investment and exports seems mixed and surprisingly we did not find any empirical evidence supporting the notion of imports as an additional source of growth (as the endogenous growth models emphasize) for the case of China.

In contrast, in the papers that have focused on human capital in China, we did find a positive

[10] These studies neglect the role of human capital and innovation activities.

relationship between human capital and growth (Chen and Fleisher, 1996; Chi, 2008). Often these analyses are applied at regional level, probably due to a lack of data. In addition, in a study using growth accounting methods, Wang and Yao (2003) emphasized the relevance of human capital on growth at the national level from 1952 to 1999. However, their method does not allow casual relations to be established among the variables of interest and this is one of the goals of this paper.

Finally, as far as we know, there is no empirical evidence on the relationship between real exchange rate and growth in the case of China, besides the fact that it has been qualified by Rodrik (2008) as "the most fascinating (and globally significant) case" of association between undervaluation and growth. In recent decades, China has undergone a rapid increase in economic growth, and also international trade, and simultaneously the position of the Renminbi has changed "from an overvaluation close to 100 percent to an undervaluation of around 50 percent".[11] Two interesting questions, both from the point of view of their implications in the sources and structural effects of Chinese growth and from the perspective of their implications in economic policy, need answering here: (1) To what extent has the increase in the commercial flows been among the causes of Chinese growth? Or, on the contrary, (2) Has such a large part of its commercial expansion and increased growth resulted simultaneously from a policy of undervaluing the exchange rate? Thus, one of the objectives of the paper is to unravel the extent to which depreciation of the real exchange rate is important for Chinese growth.

3. A Time Series Analysis of Chinese Growth

In the empirical analysis we used annual data from 1965 to 2000 on Chinese output (GDP) and productivity growth rates, jointly with the rate of physical capital accumulation, per capita human capital accumulation, R&D expenditure, three alternative variables of openness to trade (exports-to-GDP ratio, imports-to-GDP ratio or trade-to-GDP ratio), and the real exchange rate. Furthermore, we also used two alternative measures of productivity: labour productivity (output per worker) and total factor productivity (TFP, hereinafter). All the variables in levels are expressed in real terms and in natural logarithms (except the ratio of exports, imports or trade to GDP and the human capital).[12]

[11] Rodrik (2008), p. 3. We can see similar results on real exchange rate misalignment in China in Zhang (2001). A detailed analysis and chronology of exchange rate policy in China can be found in Lin and Schramm (2003).

[12] Further details about the definition and measurement of the variables are provided in the Data Appendix.

Our empirical strategy to test the relevance of endogenous growth models and their implications in the case of China has two steps. First, we analyse the time series properties of growth rates, using different methods to test for the level of integration of time series, because they can provide important information regarding the relevance of different growth models. Specifically, as stated by Jones (1995), if the growth rate of a country is fit well by a process with a constant mean and very little or no persistence, then either nothing in this country has had a large, persistent effect on the growth rate, or whatever persistent effects have occurred have been offsetting, or the endogenous growth models are misleading. Similarly, but from the opposite point of view, Lau (1999) "shows that a unit root has to be present in the autoregressive polynomial of the variables generated by an endogenous growth model". And second, following the above arguments, we test the trending properties of potential determinants of long-run growth (including physical and human capital accumulation, openness to trade and R&D investment) and whether permanent changes in these variables have permanent effects on the GDP, labour productivity and TFP growth rates. To do this, and taking into account the stochastic properties of the data and the potential endogeneity among the variables that were considered, we examined the existence of long-run relationships using the cointegrated VAR methodology.

3.1. Time Series Properties of the Data: Unit Root Tests

Many papers have used the traditional Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests and found that the levels of output or labour productivity are integrated of order one and their growth rates are stationary, exhibiting little or no persistence; yet, little empirical evidence seems to exist that employs alternative tests to improve the model specification and the inference for the case of China. However, looking at their graphs,[13] there is a suspicion that the level of GDP, and productivity could be integrated of order two. This possibility could probably be explained by two facts: the negative shocks experienced by the Chinese economy during the 1960s and 1970s and its rapid growth in the last two decades. Nevertheless, given the relevance of distinguishing between growth rates generated by a unit root process from growth rates with some persistence but mean reverting, we are going to re-examine this issue more closely.

[13] Available upon request.

Although the ADF and Phillips-Perron test 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, and it is well known that "these tests generally suffer from two problems. First, many tests have low power when the root of the autoregressive polynomial is close to but less than unity. Second, the majority of tests suffer from severe size distortions when the moving-average polynomial of the first differenced series has a large negative root."[14] The consequence is over-rejection of the unit root hypothesis. Thus, we are going to use additional tests for unit roots with the aim of mitigating these problems. First, we use the test suggested by Kwiatkowski et al. (1992). This test reverses the hypothesis of traditional tests, assuming that under the null hypothesis the time series are stationary. Second, following Ng and Perron (2001), we use their much larger and more powerful unit root test (M tests) to overcome the lower power of traditional tests due to size distortions, as well as to provide a more adequate selection of lag length. Ng and Perron (2001) developed a unit root test based on GLS detrending in order to achieve substantial power gains, which allow a more precise autoregressive spectral density estimator, provided that the truncation lag is selected appropriately. These authors suggested a Modified AIC rule to select the truncation lag instead of the more usual AIC rule, which tends to select a lag length that is too small, due to its under-estimating the cost of a low-order model in several circumstances.[15] Finally, as is argued in Lanne and Lütkepohl (2002) and Lanne et al. (2002), it is also known that the standard unit root tests have reduced power if they are applied to time series with structural shifts. Thus, building on a proposal by Saikkonen and Lütkepohl (2001), Lanne et al. (2002) developed a unit root test to deal with very general non-linear deterministic shift functions. Additionally, the estimation of deterministic terms by a GLS procedure is also considered. The simulations carried out by these authors showed that tests which estimate the deterministic term by a GLS procedure under the unit root null hypothesis are also superior in terms of size and power properties compared to tests which estimate the deterministic term by OLS procedures.

In Table 1 we present the summary of results from our analysis of the time series properties of GDP, labour productivity and TFP growth rates using the five aforementioned unit root tests, with

[14] Ng and Perron (2001), pp. 1519-1520.

[15] Perron and Ng (1996) showed that the M tests have dramatically smaller distortions than most (if not all) unit root tests in the literature in cases of negative moving-average errors if the autoregressive spectral density estimators defined above are used in conjunction with a suitably chosen k.

different determinist terms (none, constant and constant with trend). These tests are the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), the test developed by Kwiatkowski et al. (1992) (KPSS), the Ng and Perron (2001) test, and the unit root test with breaks developed by Lanne et al. (2002) (LLS).

The results presented in Table 1 can be described as mixed.[16] In both cases we reject the null of unit root in the GDP, labour productivity and TFP growth rates when the constant and constant with trend are included, at all levels of significance, according to the ADF and PP tests. However, with the KPSS test we reject the null that time series growth rates of GDP, labour productivity and TFP are stationary,[17] and according to Ng and Perron and the LLS tests it is not possible to reject the null of unit root in growth rates in all cases.[18] Thus, although the issue of the order of integration should be examined more carefully due the continuous efforts made to develop new tests, it is possible to think that the tests developed by Ng and Perron (2001) and Lanne et al. (2002) are the ones with the most precise power compared with the others used in this paper. We conclude that all series can be characterized as being integrated of order one.

[INSERT TABLE 1 NEAR HERE]

Finally, although we accept that the growth rates of output, labour productivity and TFP are integrated of order one, this property would only be compatible with models of endogenous growth if the variables that are potential determinants of growth were also integrated of order one and there is a cointegration relationship between them.

The results from the unit-root tests of the different variables considered in the rest of the work can be seen in the appendix. We conclude that all variables except the stock of physical and human capital are integrated of order one in levels. The stock of physical capital and human capital are integrated of order two with the majority of the tests considered; we therefore turn these variables into the first differences to look for long-run relationships among them and growth rates.

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[16] We also performed the stationary test implemented in CAT for RATS, and the results suggested that the growth rates are not stationary.
[17] When the constant term is included, stationary cannot be rejected in the case of TFP growth rate.
[18] We employed the modified AIC criterion to select the number of lags in the Ng-Perron Test. For further details, see Ng and Perron (2001).

3.2. Accounting for Long-run Determinants of Growth

a) Econometric Methodology

In order to carry out the cointegration analysis, we use the cointegrated VAR model proposed by Johansen (1988 and 1995), Johansen and Juselius (1990 and 1994) and Juselius (2007). One of the advantages of this methodology is its flexibility. It allows the interdependence of our variables to be tested by initially considering all relevant variables as endogenous, and then explicitly analysing the weak exogeneity of one or more of them. In addition, the possibility of combining long-run and short-run information in the data by exploiting the cointegration property together with the possibility of establishing casual economic relationships among the variables of interest are probably the most important reasons why the cointegrated VAR model continues to receive the interest of both econometricians and applied economists (Juselius, 2007).[19] We follow the most parsimonious approach of our initial model and then we reduce the model by imposing testable restrictions on the non-significant parameters in order to achieve economic interpretability (Hendry and Mizon, 1993; Juselius, 2007).

The unrestricted VAR model is given by:

$$\Delta Y_t = \alpha\beta_i^{'}\begin{pmatrix} Y \\ Z \\ t \\ D_s \end{pmatrix}_{t-1} + \sum_{i=1}^{k-1}\Gamma_i \Delta Y_{t-i} + \sum_{i=0}^{k-1}\omega_i \Delta Z_{t-i} + \sum_{i=0}^{k-1}\theta_i \Delta D_{st-i} + \varphi D_t + \mu + \varepsilon_t \qquad (11)$$

$$\varepsilon_t \sim NIID(0,\Sigma) \quad t = 1 \ldots T$$

where Y_t is the matrix of endogenous variables since the beginning, α and β are matrices of dimension $p \times r$; α denotes the direction and speed of adjustment toward equilibrium and β' is the matrix of the cointegrated vectors. Z_t is the matrix of the weakly exogenous variables by assumption since the beginning, t is the linear trend restricted to the cointegration space,[20] and D_s is the matrix of the shift dummies restricted to the cointegration space to guarantee a reasonable degree of stability

[19] For example, it is possible to find other works that employ the cointegration techniques applied to the Chinese economy, like Chow (1987), Li (2000), Yao (2000) or Narayan et al. (2007), among others.

[20] The reason for including a trend in the cointegration space is that when the data show distinct tendencies we need to allow for linear trends in the cointegration relationships when testing for the cointegration rank.

of our estimated parameters.[21] $\{\Gamma, \omega, \theta\}$ are the unrestricted parameters in the dynamics of the model, whereas φD_t denotes the two additional unrestricted permanent dummies and μ is a vector of unrestricted constants. Finally, we assumed that the error term ε_t is an i.i.d. Gaussian sequence $N(0, \sum)$ and the initial values, $Y_{-k+1}, \ldots Y_0$, are fixed.

Initially, given the large number of potentially endogenous variables, and following the specific-to-general approach used by Juselius and MacDonald (2000, 2004), we started the analysis with a five-dimensional system that alternatively included the GDP, labour productivity or TFP growth rate (*g(GDP), g(GDP/L) or g(TFP)*), jointly with the rate of physical capital accumulation (*g(K)*), R&D expenditure (R&D), openness – alternatively measured by the export-to-GDP ratio *(X/GDP*), imports-to-GDP ratio (*M/GDP*) or trade-to-GDP ratio (*T/GDP*), and the real exchange rate (*RER*).[22] Once this model had been identified, we extended our empirical analysis by including the per capita human capital accumulation (*ΔHC*). In all cases, and in order to capture the influence of the rest of the world on Chinese economic performance, we introduced the US GDP growth rate (*g(GDPUSA)*) as an exogenous control variable.[23]

In addition, we also performed the weak exogeneity tests, the conclusion being that GDP or TFP growth and physical capital accumulation are the only endogenous variables in the GDP and TFP models respectively. The same happens when labour productivity is analysed, except when imports are used as a proxy of openness; in this case the endogenous variables were labour productivity growth and the real exchange rate.[24] To conclude the specification of our models, we found that two

[21] The shift dummy takes the form (0,0,1,1,1) and two shift dummies (1978 and 1994) were included in the GDP model, and another two (1978 and 1984) were included in the labour productivity and TFP model. The permanent unrestricted dummy takes the form (0,0,1,0,0) and two others (1976 and 1989) were included in all the models. It is possible to determine the break through the battery of stability tests. See Juselius (2007).

[22] Given that the majority of variables could be considered I(1) in levels with the traditional tests of unit roots, it is reasonable to ask for the results of this analysis using the variables in levels . In Herrerías and Orts (2009) we do this with very similar results. In that paper, our findings suggest that openness and capital accumulation are the main determinants of labour productivity in the long run (with positive effects of competitiveness in some cases), while R&D expenditure promotes growth indirectly, by stimulating capital accumulation in the long run.

[23] The US GDP level seems to be non-stationary with the majority of the tests employed and its growth rate is stationary, but there are some tests that put that conclusion in doubt. Nevertheless, we use it as a control variable, thinking that it could have more influence in the short-run dynamics of the model than in the long run.

[24] Weak exogeneity test and the stability tests were omitted in the paper to save space. These tests are available from the authors on request together with the residual analyses.

lags are enough to prevent autocorrelation problems and to capture the dynamic effects following the LM test.

Once we have a well-specified model, its possible to obtain the number of long-run relations *(r)*, and the common driving trends *(p-r)* with the likelihood ratio (LR) trace test, the roots of the companion matrix and the graphics of the long-run relations expressed as deviations from steady-state.[25] The procedure starts by examining the null hypothesis $r=0$ and if this is rejected, the next null hypothesis, $r=1$, is examined until it is not rejected. Thus, with all this information, we can conclude that everything seems to indicate that just one long-run relationship exists in all the models estimated in this paper. To achieve economic interpretability of these long-run relationships, over-identifying restrictions have been included in the non-significant coefficients that were accepted by the data.[26] Furthermore and in accordance with the battery of stability tests, the concentrated version of the model seems reasonably stable.

b) Empirical Results

Our main results are presented in Table 2. This Table is concerned with the long-run relationships between the variables considered in each model, that is, the cointegrating vectors. All the long-run relationships are expressed as deviations from the steady state, normalized in GDP, labour productivity and TFP growth rates, respectively. Nevertheless, it is not possible to interpret the coefficients in the cointegrated VAR model as in the traditional econometric methods, given that a shock to one variable is transmitted to all variables via dynamics of the system until the system has found its new equilibrium position (Juselius, 2007). Moreover, it is possible to examine the direction of the causality in the Granger sense by analysing the significance of the coefficients in the cointegrating vectors and through the coefficient of the error correction mechanisms (*ecm*) in the dynamics.[27] This coefficient has to be negative and significant in the first difference equation of the variable in which the cointegrating vector has been normalized so that it can be interpreted in

[25] In accordance with Johansen (1995), the vector process is based on asymptotic distributions that depend on the deterministic terms in the VAR model and this is why we have simulated the distribution of the rank test in CATS for RATS. Due to the large number of models that have been estimated, the rank test and the root of companion matrix as well as the graphs of the long-run relations are all available upon request. The determination of the rank was based on all this information. We have accepted one cointegrated vector for all models that were estimated.
[26] See Juselius (2007).
[27] See Appendix B for the dynamic structure of all the models.

economic terms. For all the cases, that is, in the *Δg(GDP)*, *Δg(GDP/L)* and *Δg(TFP)* equations, it can be seen that they are error-correcting with the respective long-run relationship found in each model. The speed of adjustment toward equilibrium is reasonably fast, hence indicating that these economic relations are stationary.

[INSERT TABLE 2 NEAR HERE]

Returning to our long-run relationships in Table 2, in Panel A we report the estimates of GDP growth rate with and without human capital together with the three alternative measures of openness, that is, our initial model and the extended model with human capital. In all the cases the coefficients show the expected signs and are significant. Thus, Panel A in Table 2 describes how net investment, openness and R&D expenditure account for GDP growth rate in the long run. Furthermore, when human capital is included, we found that it is an additional factor in accounting for GDP growth, except when imports are included. The direction of the causality is unidirectional and runs from physical and human capital accumulation, openness, and R&D expenditure, to GDP growth rate. In Panel B in Table 2, we present the estimates of labour productivity growth rate in the same way as GDP growth, and the estimated coefficients are also significant and have the expected signs. We found that labour productivity responds to the fluctuation of net investment, openness and R&D activities and hence they have a positive long-run effect on labour productivity growth rate. Similar results were found regarding the effect of human capital on labour productivity compared with the previous model. Once again, the direction of the causality is unidirectional running from net investment, openness, R&D and human capital to labour productivity.

Finally, in Panel C of Table 2, we report the results of the estimates with TFP.[28] Although the previous analyses provide us with relevant information about the potential determinants of long-run growth in the Chinese economy, the analysis of TFP can offer us a complementary view. Given the strong differences between the implications that the Solow-type growth models and the endogenous growth models have on TFP, it could help us to better understand the nature of Chinese growth. Yet it could also be useful to provide a more appropriate explanation of the role played by factor

[28] We thank one of the referees for this suggestion

accumulation and productivity or efficiency gains in the process of growth that has taken place over the last four decades in China. Following the Solow-type models, TFP has to be given exogenously and must not to be permanently affected by changes in agents' behaviour or government policy. However, according to endogenous growth models, the opposite is true and it has to be determined by internal forces of the economic system. Our measure of TFP has a straightforward interpretation: it is an index of the joint efficiency with which labour and physical capital are used or, in other words, it is the component of economic growth that cannot be explained by labour and physical capital accumulation.[29] As before, the cointegrating vectors found were normalized in the TFP growth rate for each model. In all cases it can be observed that all coefficients are significant and have the expected sign. We found that the main drivers of the Chinese growth rate and the output per worker growth rate are also the main sources of TFP growth. Thus, in our initial models, capital accumulation, innovation activities and openness to trade have a direct and positive influence on TFP growth rate in the long run. Moreover, when human capital is introduced into these models, we found that it has a positive long-run effect on TFP growth, except when the imports-to-GDP ratio is used as a proxy of openness.

Thus, in agreement with the endogenous growth models, and as can be seen in Table 2, the coefficient of physical capital growth rate is highly significant after identifying these long-run relationships, and the restrictions equal to zero in these coefficients are not accepted by the data. As is evident from (10), the AK-type models imply that the rates of growth and net investment move in the same direction in the long run. Similar conclusions may be found with regard to human capital. Our results suggest that per capita human capital is highly significant when trade-to-GDP or exports-to-GDP are included in the models. However, when imports were examined, we found that human capital is not significant in these models. This effect is probably accounted for by the fact that the majority of imports consist in capital and intermediate goods coming from developed countries and their influence on growth rates is quite strong, thereby weakening the modest influence of human capital. Analogously, and in accordance with the predictions of the R&D-based growth models, a permanent increase in the level of resources devoted to R&D leads to a permanent increase in growth rates and productivity, as shown in Table 2. The innovation activities are significant

[29] For more details, see Data Appendix.

regardless of the trade measure utilized.

In addition, and in line with the predictions of the new growth theory on the effect of openness on the rate of economic growth, we found that openness to international trade has played a significant role in economic growth in China. Moreover, this trade effect is robust to the openness measure that was utilized. In line with other studies, like Shan and Sun (1998), Liu et al. (1997 and 2002) or Siebert (2007) for example, we found that exports have contributed exogenously to stimulate long-run growth, which is consistent with the *export-led* hypothesis. Additionally, unlike other studies, we found new evidence that imports have also favoured economic growth during the period under consideration, thus following the *import-led* growth hypothesis. In this sense, our findings are more in agreement with the defenders of the positive effects that openness to trade has on growth than with those who argue that trade is more a consequence of growth than one of its causes. In our case, however, openness only has a positive role on growth when capital accumulation (in the broad sense of the term) and R&D are considered jointly.[30] This somehow reconciles the visions of the strictest defenders of the beneficial effect of openness on growth (Frankel and Romer, 1999; Baldwin, 2003, among others) with the one belonging to those somewhat more heterodox authors who have highlighted the influence of other domestic factors on the process of growth in developing economies (for example, Rodrik, 1995).

These findings, together with the permanent effects of R&D expenditure and physical and human capital on the growth rate and productivity of the Chinese economy are more consistent with some version of the endogenous growth models than with Solow's model of growth.

In order to finish the analysis of our long-run results, we have to mention the singular role played by the real exchange rate. In all the cases in which it is significant, we found that depreciation has a positive effect on growth. This evidence is consistent with the hypothesis that the Renminbi has been employed as an additional instrument of economic growth policy. Everything seems to indicate that maintaining a competitive exchange rate has been a suitable factor in Chinese growth over the period under consideration, and its influence has worked for channels other than through stimulating trade (Gala, 2008; Rodrik, 2008). However, as expected, competitiveness gains do not positively affect the long-run TFP, which makes us think that it exerts its positive effect directly on

[30] Thus, our results are more in line with the works of Levine and Renelt (1992), Baldwin and Seghezza (1996) or Wacziarg (2001).

GDP, but does not affect the efficiency with which the productive resources are used. This difference is fundamental for policy actions, since identifying a competitive or undervalued exchange rate with a suitable strategy to improve the productivity or efficiency gains in the long-run can be misleading.

4. Testing for Catching-up and Convergence

After determining the factors that potentially account for productivity and output growth rates in the Chinese economy, the next question to be examined is whether this rapid growth is helping to narrow the gap between output per worker in China and in one of the world's most advanced economies – the USA.[31] Specifically, we investigate pairwise GDP per worker convergence between China and USA on the basis of the time series unit root tests. This issue is related with the concept of stochastic convergence developed by Carlino and Mills (1993), Bernard and Durlauf (1995) or Evans and Karras (1996), among others. In this context, stochastic convergence implies that shocks to output per worker in a country should be transmitted to the rest of the countries, and the differences in labour productivity between countries must disappear over time, that is, this difference must be stationary. Alternatively, the absence of convergence implies that GDP per worker differences between countries must contain a unit root. Since the test usually includes a constant term, stochastic convergence implies that incomes converge to a country-specific compensating differential. In consequence, stochastic convergence is consistent with conditional convergence (Strazicich et al., 2004).

Bernard and Durlauf (1995) found little evidence of conditional convergence among a larger sample of countries using the notion of time series through application of the Dickey-Fuller unit root test. In addition, the time series approach used by Quah (1990) and Ben-David (1994) did not reveal any general evidence of convergence among a large number of countries using the Summers-Heston (1988) database. However, more recent evidence employing more advanced and sophisticated unit root tests, which allow for either structural breaks or non-linearities, find more evidence in favour of convergence. This is the case, for example, of Strazicich et al. (2004) for OECD countries, Christopoulos and Tsionas (2007) for states of the USA, Galvao and Gomes (2007) for Latin-American countries, and Carrion-i-Silvestre and German-Soto (2007) for the case of Mexico, among

[31] We thank one of the referees for this suggestion.

others.

Traditionally, researchers only consider two opposite alternatives: a particular economy has either experienced convergence or it is diverging with respect to the reference country. Hence, they often fail to contemplate an additional possibility i.e. that the economy under analysis is in the transition towards the steady-state and therefore the converging process has not yet been completed. In this sense, Oxley and Greasley (1995) refine the concept of convergence highlighted by Bernard and Durlauf (1995) and distinguish between two concepts: catching-up and long-run convergence. The two concepts are both related to the fact that the difference in the output per worker between USA and China must be stationary. However, while catching-up is consistent with the existence of a time trend in the deterministic process, long-run convergence is not. Hence, the concept of catching-up "relates to economies out of long-run equilibrium over a fixed interval of time", but which are in the process of narrowing the gap between them, while long-run convergence "relates to some particular period T equated with the long-run equilibrium" and "implies that catching-up has been completed".[32] In terms of our analysis, long-run convergence implies both the absence of a unit root in the differences of the log per worker real GDP between USA and China and the absence of a time trend in the deterministic process.

Formally and using the traditional Dickey-Fuller unit root test as a benchmark, it is possible to test these different notions for the case of China with respect to the US economy (as a reference country) in terms of labour productivity differentials.[33] One can then specify the unit root test as follows:

$$\begin{aligned}\left((GDP/L)_{USA} - (GDP/L)_{CH}\right)_t &= \mu + \alpha\left((GDP/L)_{USA} - (GDP/L)_{CH}\right)_{t-1} + \beta t \\ &+ \sum_{k=1}^{K} \delta\Delta\left((GDP/L)_{USA} - (GDP/L)_{CH}\right)_{t-k} + \varepsilon \qquad (12)\end{aligned}$$

where $(GDP/L)_{US}$ and $(GDP/L)_{CH}$ are the US and Chinese labour productivity respectively.[34] Divergence under this notion implies that $\alpha = 1$, that is, productivity differentials contain a unit root.

[32] Oxley and Greasley (1995), p. 79.

[33] We made use of the same span as in the previous estimations. Data for the USA were taken from the BEA and BLS statistical offices. All variables are expressed in logs.

[34] We assume here that (at least initially) the US economy has greater labour productivity than the Chinese economy.

However, if $\alpha < 1$ and $\beta \neq 0$, then the result implies that the Chinese economy is catching up with the USA, but the convergence process has not been accomplished yet. In order to find long-run convergence the process has to be stationary without a deterministic trend, that is, $\alpha < 1$ and $\beta = 0$.

Due to the fact that these hypotheses can only be tested using the unit root test, the same discussion as the one we explained in depth earlier about the power of each unit root test reappears here. Thus, our empirical strategy was the same as the one employed earlier and we perform the analysis with a battery of unit root tests to investigate the different hypotheses. In particular, we start with the conventional ADF and Phillips-Perron unit root test as a benchmark, and then we utilize an improvement of these tests developed by Ng and Perron (M-Tests) as well as the KPSS test that changes the null hypothesis. However, there is evidence that suggests that by ignoring the structural breaks one can conclude divergence rather long-run convergence or catching-up (Strazicich et al., 2004), so we also consider the possibility of structural breaks in the model along with the respective unit root test. The results from this analysis are reported in Table 3.

[INSERT TABLE 3 NEAR HERE]

Several conclusions can be drawn from the table above. First, both ADF and Phillips-Perron unit root tests clearly indicate that the US and Chinese economies are diverging in terms of labour productivity. However, as discussed before, the performance of these tests is usually weak. In contrast, when we consider other tests like KPSS and Ng and Perron Tests, the divergence that was found before now becomes a catching-up process, due to the fact that the labour productivity differences between this pair of countries, $(GDP/L)_{USA} - (GDP/L)_{CH}$, are trend stationary. In addition, although from the LLS test, which allows for a structural break (in 1978), it is possible to reach the same conclusion a priori, a closer look, however, reveals that the trend is not significant and thus indicates long-run convergence. Given this ambiguity compared to previous results, we decided to perform an additional unit root test proposed by Perron (1997), which allows for one additive outlier with a change in the slope only but both segments of the trend function are joined at the time break. The results from this last test confirm our previous findings, that is, that Chinese labour productivity is probably catching up with that of the USA. Thus, although all the tests reject the hypothesis of long-run convergence between US and Chinese labour productivity, most of them support the existence of a catching-up process, which suggests that the gap between the labour productivity of the two countries is becoming smaller. This result is quite robust to the different unit root tests employed. This expected finding is probably related with our previous results which showed that economic policies that promoted investment, openness to trade, innovation activities and human capital positively influence labour productivity and output growth rates as well as TFP in the long run.

5. Conclusions

The main objective of this paper has been to unravel the relevance of endogenous growth models in explaining the Chinese economic growth from 1965 to 2000, more for the policy and economic implications of this type of models than with the aim of testing its empirical relevance explicitly. Specifically, we have explored the time series properties of the growth rates of GDP, labour productivity and TFP, and the role played in their long-run determination by physical capital accumulation and their interactions with other sources of economic growth, such as improvements in per capita human capital, R&D expenditure, openness to trade, and competitiveness. Additionally, in order to provide evidence of the robustness of our results, we considered three alternative measures of trade openness (exports, imports and overall trade to GDP).

Our findings suggest that the growth rates of GDP, labour productivity and TFP are non-stationary, that is, they exhibit large persistent movements. Additionally, capital accumulation (understood in a broad sense namely, including physical and human capital) is among the most important driving forces behind China’s growth. Furthermore, in accordance with different extensions of endogenous growth models, we found that the level of the resources involved in the R&D activities and openness (independently of the measure used: trade, exports or imports to GDP) guide and positively affect output, labour productivity and TFP growth rates in the long run. Finally, we found evidence that maintaining a competitive real exchange rate has also played a significant role in the explanation of the long-run rate of growth of output and labour productivity in the period that was analysed. However, these improvements in competitiveness do not have any positive influence on long-run total factor productivity. These findings, considered jointly, allow us to state that the growth process experienced by the Chinese economy has not only been the result of a process of factor accumulation, but at least this factor accumulation has co-existed with significant efficiency gains in the long run. In effect, as long as the growth rate of TFP is measuring the increase in efficiency with which all factors of production are used (that is, improvements in technological progress or efficiency gains), our results imply, first, that it is determined by forces that are internal to the economic system (capital accumulation, improvement of per capita human capital, innovation activities and openness); second, that the growth rate of output per worker is only partially explained by capital accumulation (capital deepening); and, third, that capital accumulation (i.e. investment effort) also has a positive effect on the rate of growth of technological progress or efficiency with which the productive factors are used. That is, capital accumulation has a positive effect on the growth rate of output (or output per worker), not just because it boosts capital formation per worker but because of its potential to enhance the quality of the installed capital stock. The reason for this probably lies in the fact that new capital is assumed to bring with it better technology than that which was previously installed (due to embodied technological progress). Thus, although it is difficult to discriminate strictly among different models of growth, our results seem to be more consistent with the implications of certain versions of the endogenous growth models than with the Solow-type models of growth.

Finally, we also found that China's labour productivity is undergoing a process of catching-up with US labour productivity. Therefore, although we reject the hypothesis of long-run convergence between China and USA in all cases, our results do lend support to a weaker version of the convergence hypothesis which suggests that the gap between the labour productivity of the two countries is becoming smaller.

Thus, from the perspective of increasing their rate of economic growth and catching-up, the economic development strategy pursued by the Chinese authorities (by stimulating physical and human capital accumulation, innovation activities and openness) has been worthwhile. There are however some problems that may be a source of increasing constraints in the future. First of all, although physical capital has been found to be a source of long-run growth in China, the sustainability of the high rates of saving and investment to GDP is dubious, not only because this strategy has significant costs in terms of low levels of consumption, but because in the future it could affect the productivity of capital and the efficiency of investment. Consequently, this scenario will affect the pace at which technological innovation is incorporated into the stock of installed capital and can weaken the forces that offset the tendency towards diminishing returns in the accumulation of capital.

However, given that we have found that human capital and innovation activities exert a positive and direct influence on economic growth, and that these two key factors are relatively scarce in the Chinese economy, both in absolute terms and when they are compared with developed countries, there is still considerable scope to stimulate technological innovation and human capital accumulation, while at the same time making growth more balanced and sustainable. From this perspective, China could relax the effort made on saving and stimulate other sources of technological improvement, like the accumulation of knowledge and the propensity to innovate.

Finally, the various reforms implemented to facilitate the integration of China into the international markets have made it one of the largest traders in the world, and everything seems to indicate that this strategy has also given good results. However, high dependence on imported capital and intermediate goods, as well as, an increasing need for high levels of exports does not seem sustainable, because it increase foreign dependence of the external market, making the economy more exposed to external shocks.

This last warning might also be affected by the sustainability of exchange rate policy. Thus, although until now maintaining a competitive exchange rate seems to have served as a stimulus to growth, it is not a source of improvement of the long-run productivity (TFP) and it seems difficult to systematically keep it up because of the imbalances that this strategy entails in terms of reserve accumulation and its implications for monetary policy management.

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Table 1: Unit Root Tests (Value of test statistic)

	ADF Test			Phillips-Perron Test			KPSS Test	
	Null: Unit Root			Null: Unit Root			Null: Stationary	
	none	const.	trend	none	const.	trend	const.	trend
g(GDP)	-1.37	-6.62 *	-6.70 *	-2.25**	-8.10*	-8.26*	0.50**	0.36*
g(GDP/L)	-0.72	-5.39*	-5.98 *	-3.66*	-4.33*	-7.31*	0.43*	0.50*
g(TFP)	-5.40***	-5.39***	-3.89**	-4.80***	-5.99***	-6.48***	0.26	0.32***

	Ng-Perron Test						LLS Test	
	Null: Unit Root						Null: Unit Root	
	Constant			Trend				
	MZ_α	MZ_t	MSB	MZ_α	MZ_t	MSB	None	trend
g(GDP)	-2.17	-0.95	0.44	-11.51	-2.39	0.20	-2.36	-2.57
g(GDP/L)	-1.41	-0.74	0.53	-17.00*	-2.91*	0.17*	-1.64	-2.17
g(TFP)	-16.99	-2.91	0.17	-17.07	-2.91	0.17	-3.45	-2.76

Note: The tests were performed with Eviews and JMULTI. * Rejection of the null at 10%, ** Rejection of the null at 5%, *** Rejection of the null at 1%.

Table 2. Cointegrating Long-Run Relationships

A) GDP Models

Initial Models	g(GDP)	g(K)	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.58 [-7.48]	-0.09 [-10.42]	-0.45 [-13.37]			0	$\chi^2(2)$=2.513(0.285)
ecm_2	1	-0.60 [-4.82]	-0.08 [-8.29]		-0.58 [-5.10]		-0.10 [-4.23]	$\chi^2(1)$=2.396(0.122)
ecm_3	1	-0.28 [-3.51]	-0.08 [-8.96]			-0.74 [-12.06]	0	$\chi^2(2)$=1.120(0.571)

Models with Human Capital	g(GDP)	g(K)	ΔHC	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.52 [-5.69]	-0.17 [-7.62]	-0.09 [-11.04]	-0.34 [-6.14]			-0.23 [-6.27]	$\chi^2(2)$=4.388(0.111)
ecm_2	1	-0.66 [-5.22]	-0.25 [-8.23]	-0.08 [-7.56]		-0.51 [-4.33]		-0.36 [-9.51]	$\chi^2(2)$=1.284(0.526)
ecm_3	1	-0.38 [-5.68]	0	-0.07 [-10.02]			-0.71 [-13.80]	0	$\chi^2(3)$=1.737(0.629)

B) Labour Productivity Models

Initial Models	g(GDP/L)	g(K)	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.77 [-9.55]	-0.07 [-9.76]	-0.62 [-14.19]			0.11 [5.70]	$\chi^2(2)$=0.165(0.921)
ecm_2	1	-0.86 [-8.44]	-0.08 [-8.41]		-0.95 [-11.40]		0	χ^2 (3)=1.79 (0.61)
ecm_3	1	-0.42 [-3.85]	-0.05 [-7.57]			-1.27 [-10.42]	0.18 [5.03]	$\chi^2(3)$=0.825(0.844)

Models with Human Capital	g(GDP/L)	g(K)	ΔHC	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.71 [-9.03]	-0.10 [-6.20]	-0.07 [-9.41]	-0.63 [-14.51]			0	$\chi^2(4)$=7.856(0.097)
ecm_2	1	-1.01 [-9.00]	-0.05 [-2.73]	-0.07 [-7.72]		-1.07 [-10.40]		0	$\chi^2(3)$=4.911(0.178)
ecm_3	1	-0.57 [-5.72]	0	-0.05 [-5.72]			-1.40 [-11.33]	0.24 [6.14]	$\chi^2(4)$=1.946(0.746)

C) TFP Models

Initial Models	g(TFP)	g(K)	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.66 [-7.11]	-0.07 [-7.11]	-0.55 [-10.47]			0	$\chi^2(3)$= 0.940(0.625)
ecm_2	1	-0.83 [-7.64]	-0.07 [-6.92]		-0.86 [-9.76]		0	χ^2 (3)= 2.177 (0.537)
ecm_3	1	-0.34 [-3.21]	-0.06 [-5.62]			-1.23 [-9.69]	0	$\chi^2(3)$= 1.036 (0.793)

Models with Human Capital	g(TFP)	g(K)	ΔHC	R&D	T/GDP	X/GDP	M/GDP	RER	Restrictions
ecm_1	1	-0.74 [-8.94]	-0.10 [-5.47]	-0.06 [-7.62]	-0.50 [-13.47]			0	$\chi^2(4)$=7.84(0.098)
ecm_2	1	-1.05 [-8.73]	-0.17 [-6.15]	-0.06 [-6.63]		-1.05 [-9.77]		0	$\chi^2(4)$= 5.860 (0.119)
ecm_3	1	-0.44 [-4.39]	0	-0.06 [-5.69]			-1.53 [-12.21]	0	$\chi^2(5)$= 7.182 (0.127)

Note: We show only the coefficients of the stochastic variables; the deterministic components are available upon request.
t-statistics in brackets

Table 3: Unit Root Tests of $\left(GDP/L\right)_{USA} - \left(GDP/L\right)_{CH}$ (Value of test statistic)

Unit Root Tests	Constant	Constant and Trend
ADF Test	0.92	-2.95
Phillips-Perron Test	2.02	-1.73
KPSS Test	0.75***	0.17
Ng and Perron (MSB Test)	0.72	0.15**
Ng and Perron (MZ α)	1.51	-19.93***
Ng and Perron (MZ t)	1.09	-3.10**
LLS Test	0.48	-3.25**
Perron (Endogenous Break)	-	-5.30**

Note: * indicates rejection of the null at 10%, ** rejection of the null at 5%, and *** rejection of the null at 1%

Data Appendix

Our main source of data for China is "China Compendium of Statistics 1949-2004" edited by The National Bureau of Statistics of China (NBS).

Chinese Output (*GDP*): Gross Domestic Product at constant prices.

Employment (*L*): Refers to Persons aged 16 and over who are engaged in gainful employment and thus receive remuneration payment or earn business income.

Labour Productivity (or output per worker) (*GDP/L*): This was obtained by dividing GDP by Employment. Authors' own calculations.

Total Factor Productivity (*TFP*): We estimate the TFP from a Cobb-Douglas production function, assuming that output only depends on capital and labour, that is,

$$TFP_t = \frac{Y_t}{K_t^{\gamma} L_t^{(1-\gamma)}}$$

and then the growth rate of TFP can be expressed as:

$$g(TFP)_t = g(GDP/L)_t - \gamma\left(\frac{\Delta(K/L)_t}{(K/L)_t}\right)$$

where *g(X)* is the growth rate of *X*, and γ is the share of physical capital in output. Following Chow (1993), Chow and Li (2002) and Chow (2008), we used a share of the physical capital equal to 0.6.[35]

Openness to trade (*X/GDP, M/GDP, and T/GDP*): We use three measures of openness, *exports-to-GDP ratio, imports-to-GDP ratio* and *trade-to-GDP ratio*. We use total imports and exports at customs, which refer to the real value of commodities imported and exported across China's borders. In accordance with the stipulation of the Chinese government, imports are expressed in CIF terms, while exports are expressed in FOB terms. The trade-to-GDP ratio is measured as imports- and exports-to-GDP (*T=M+X)*).

R&D expenditure (*R&D*): We use expenditure on science and technology. This refers to the government spending on science and technology (S&T), including the expenses involved in the administration of S&T, basic research, applied research, research and development, conditions and services of S&T, popularization of social science, science and technology, exchanges and cooperation of S&T, etc. We deflated *R&D expenditure* with the GDP deflator.

Real exchange rate (*RER*): The real exchange rate was calculated using the nominal exchange rate between the Chinese currency and the US dollar (Renminbi/$) and the respective consumer price indices (CPIs) from USA and China. The CPI data from USA was taken from the Bureau of Labor Statistics; the CPI from China is from the NBS.

Physical Capital Stock (*K*): We took this variable from Wu (2004). See there for further details.

Per Capita Human Capital Stock (*HC*): We took this variable from Wang and Yao (2003). See there for further details.

US GDP (GDP_{USA}): We took US GDP from the Bureau of Economic Analysis in the USA.

[35] Although other possible approximations could be performed, we use this share of physical capital in output because it was found by Chow to be the most plausible estimation of γ; furthermore, using this share, Chow found out that "accumulated capital does not lead to improved total productivity" (Chow, 1993, p.826), which provides us with the worst possible scenario to our hypothesis.

Appendix A: Unit Root Tests

Table A1: Unit Root Tests

	ADF			PP			KPSS	
	Null: Unit Root			Null: Unit Root			Null: Stationary	
	none	const.	trend	none	const.	trend	const.	trend
X/GDP	3.42	1.32	-1.07	2.90	1.55	-1.39	0.78*	0.21**
Δ(X/GDP)	-1.14	-6.25*	-5.97*	-5.61*	-6.23*	-6.92*	0.43*	0.04
M/GDP	2.54	1.14	-2.26	2.29	0.92	-1.80	0.80*	0.12***
Δ(M/GDP)	-3.89*	-4.33*	-4.63*	-3.93*	-4.37*	-4.54*	0.39***	0.06
T/GDP	-1.07	1.69	-1.07	3.15	1.69	-1.07	0.80*	0.17**
Δ(T/GDP)	-4.43*	-5.04*	-5.57*	-4.47*	-5.05*	-5.57*	0.42***	0.06
R&D	3.33	0.79	-1.47	5.25	-0.19	-2.39	0.81*	0.13***
ΔR&D	-4.85 *	-5.60 *	-5.64 *	-4.81*	-6.88*	-6.64*	0.12	0.06
RER	2.09	-1.01	-1.46	1.95	-1.01	-1.63	0.78*	0.10*
ΔRER	-4.99*	-5.66*	-5.64*	-4.99*	-5.61*	-5.58*	0.12	0.10
K	4.56	2.92	-0.72	20.88	3.82	-2.96	0.75*	0.19**
ΔK	0.18	-2.67 ***	-3.87**	-0.27	-4.01*	-4.01**	0.66**	0.13*
HC	1.59	-0.71	-1.41	3.64	-0.43	-1.48	0.80*	0.14*
ΔHC	-0.62	-1.60	-1.62	-0.93	-2.19	-2.17	0.13	0.12*
GDPUSA	4.00	-0.97	-4.93*	10.50*	-1.76	-4.13**	0.83*	0.09
ΔGDPUSA	-1.25	-4.99*	-5.01*	-2.08**	-4.99*	-5.08*	0.24	0.12*

	Ng-Perron						LLS Test	
	Null: Unit Root						Null: Unit Root	
	Constant			Trend				
	MZ_α	MZ_t	MSB	MZ_α	MZ_t	MSB	None	trend
X/GDP	3.17	1.84	0.58	-4.87	-1.16	0.23	-0.81	-1.81
Δ(X/GDP)	-20.93*	-3.09*	0.14*	-20.73**	-3.15**	0.15**	-3.72 *	-3.14 *
M/GDP	1.91	0.81	0.42	-6.02	-1.35	0.22	1.79	-1.89
Δ(M/GDP)	-18.48*	-2.85*	0.15*	-19.35**	-3.04**	0.15**	-3.84 **	-3.00**
T/GDP	2.98	1.58	0.52	-3.90	-0.95	0.24	-0.86	-2.27
Δ(T/GDP)	-20.28*	-2.99*	0.14*	-14.20 *	-2.57 **	0.18 *	-3.28 *	-3.30 *
R&D	1.38	0.78	0.56	-8.60	-1.98	0.23	-0.21	-2.61
ΔR&D	-12.19 **	-2.42 **	0.19 **	-23.66**	-3.43 **	0.14 **	-5.77*	-4.46 *
RER	0.73	0.74	1.01	-5.32	-1.53	0.28	-1.12	-1.96
ΔRER	-9.15 **	-2.13 **	0.23 **	-20.53**	-3.19**	0.15**	-3.88 *	-3.76 *
K	1.85	1.96	1.06	-3.08	-1.06	0.34	1.52	-0.70
ΔK	-0.04	-0.04	1.03	-0.94	-0.49	0.52	-3.37 **	-1.50
HC	-8.16 ***	-1.83 ***	0.22 ***	-10.46	-2.26	0.21	-1.94	-2.39
ΔHC	-10.09 **	-2.23 *	0.22 **	-10.30	-2.26	0.21	-1.70	-2.00
GDPUSA	0.76	0.48	0.63	-7.45	-1.90	0.25	0.51	-1.93
ΔGDPUSA	-0.58	-0.53	0.91	-19.56**	-3.10**	0.15**	-5.03 *	-4.67 *

Note: The tests were performed with Eviews and JMULTI. * Rejection of the null at 10%; ** Rejection of the null at 5%; and *** Rejection of the null at 1%.

Appendix B: Short-run Dynamics

Table B1: Short-Run Dynamics

A) GDP Models

	Initial Models						Models with Human Capital					
	Trade		Exports		Imports		Trade		Exports		Imports	
Variables	Δg(GDP)	Δg(K)	Δg(GDP)	Δg(K)	Δg(GDP)	Δg(K)	Δg(GDP)	Δg(K)	Δg(GDP)	Δg(K)	Δg(GDP)	Δg(K)
$\Delta g(GDP)_{t-1}$	0.43	-	0.38	-	0.37	-	0.59	0.11	0.23	-	0.30	-
	(8.52)		*(5.92)*		*(7.88)*		*(4.29)*	*(2.04)*	*(3.55)*		*(6.11)*	
$\Delta g(K)_t$							-	-	-	-	-1.07	-0.72
											(-2.61)	*(-3.62)*
$\Delta g(K)_{t-1}$	-	-0.34	-	-0.35	-	-0.53	-0.99	-0.43	-1.34	-0.44	-	-
		(-4.28)		*(-3.75)*		*(-5.92)*	*(-2.57)*	*(-2.51)*	*(-3.34)*	*(-2.78)*		
ΔHC							-	0.10	-	0.09	-0.10	-
								(6.46)		*(5.06)*	(-3.17)	
ΔHC_{t-1}							-	-	-	-	0.11	-
											(2.94)	
ΔR&D	0.21	0.05	0.21	0.04	0.20	0.05	0.16	0.04	0.21	0.06	0.18	0.05
	(7.75)	*(3.55)*	*(7.04)*	*(3.32)*	*(7.66)*	*(3.99)*	*(4.64)*	*(2.65)*	*(6.28)*	*(4.93)*	*(6.17)*	*(3.71)*
$\Delta R\&D_{t-1}$	0.07	-	0.06	-	0.07	-	0.05	-	0.04	-	0.08	-
	(4.89)		*(3.46)*		*(4.93)*		*(3.58)*		*(2.49)*		*(5.61)*	
$\Delta(T/GDP)_{t-1}$	-	0.24					-	0.18				
		(4.44)						*(5.03)*				
$\Delta(X/GDP)_{t-1}$			-0.51	-					-	-		
			(-3.74)									
$\Delta(M/GDP)_{t-1}$					0.22	0.35					-	0.35
					(2.16)	*(5.67)*						*(5.60)*
ΔRER	0.10	-	0.08	-	-	-	0.55	-	0.28	-0.17	0.15	-
	(2.48)		*(1.81)*				*(11.7)*		*(2.04)*	*(-3.19)*	*(3.82)*	
ΔRER_{t-1}	0.13	-	-	-	-	-	0.10	-	-	-	0.13	-
	(2.64)						*(2.20)*				*(3.26)*	
$\Delta g(GDP_{USA})$	0.21	-	-	-	0.26	-	0.49	-	-	-0.23	0.37	-
	(3.00)				*(3.76)*		*(6.61)*			*(-6.35)*	*(5.35)*	
$\Delta g(GDP_{USA})_{t-1}$	0.35	-	0.23	-	0.33	-	0.28	-	0.28	-	0.29	-
	(5.91)		*(3.18)*		*(5.64)*		*(4.91)*		*(3.84)*		*(5.00)*	
ecm_{1t-1}	**-1.78**	**0.37**					**-1.29**	**0.25**				
	(-12.3)	*(4.89)*					*(-5.57)*	*(2.46)*				
ecm_{2t-1}			**-1.93**	**0.39**					**-1.18**	**0.68**		
			(-10.2)	*(4.58)*					*(-3.47)*	*(5.30)*		
ecm_{3t-1}					**-1.81**	**0.44**					**-1.88**	**0.83**
					(-12.3)	*(5.49)*					*(-4.83)*	*(4.64)*
Restrictions	$\chi^2(15)=22.878$ (0.0868)		$\chi^2(19)=29.224$ (0.0625)		$\chi^2(20)=25.486$ (0.1835)		$\chi^2(18)=24.951$ (0.1263)		$\chi^2(20)=25.891$ (0.1695)		$\chi^2(20)=31.189$ (0.0527)	

Table B1: Short-Run Dynamics (Cont.)
B) Labour Productivity Models

	Initial Models						Models with Human Capital					
	Trade		Exports		Imports		Trade		Exports		Imports	
Variables	Δg(GDP/L)	Δg(K)	Δg(GDP/L)	Δg(K)	Δg(GDP/L)	Δg(R&D)	Δg(GDP/L)	Δg(K)	Δg(GDP/L)	Δg(K)	Δg(GDP/L)	Δg(RER)
$\Delta g(GDP/L)_{t-1}$	0.45	-	0.36	-	0.46	0.97	0.32	-	0.47	-	0.32	-
	(7.36)		*(5.05)*		*(5.08)*	*(1.80)*	*(6.82)*		*(7.10)*		*(5.09)*	
$\Delta g(K)_t$							-	-	-	-	1.52	-
											(10.2)	
$\Delta g(K)_{t-1}$	-	-0.23	-	-0.25	1.58	3.75	-	-	-	-0.28	-	0.77
		(-3.11)		*(-3.24)*	*(6.60)*	*(2.39)*				*(-3.56)*		*(1.93)*
ΔHC							-	0.04	0.13	-	-0.11	-
								(2.37)	(3.02)		*(-2.80)*	
ΔHC_{t-1}							-	-	-	-	0.14	-0.29
											(2.96)	*(-2.15)*
ΔR&D	0.20	0.04	0.24	0.05	-	-	0.22	0.06	0.24	0.05	0.10	-
	(6.90)	*(3.09)*	*(7.12)*	*(3.69)*			*(8.07)*	*(3.66)*	*(8.06)*	*(3.38)*	*(6.71)*	
$\Delta R\&D_{t-1}$	0.08	-	-	-0.03	0.09	-	0.08	-	0.05	-	0.10	-
	(4.79)			*(-3.59)*	*(4.97)*		*(5.94)*		*(3.62)*		*(6.30)*	
Δ(T/GDP)	0.36	-					0.31	-		-		
	(6.27)						*(4.91)*					
$\Delta(T/GDP)_{t-1}$	-0.49	-					-0.49	-		-		
	(-5.29)						*(-6.11)*					
$\Delta(X/GDP)_t$			-	-0.30					0.85	-		
				(-5.47)					*(8.12)*			
$\Delta(X/GDP)_{t-1}$			-	0.27					-	0.36		
				(4.26)						*(5.64)*		
$\Delta(M/GDP)_t$					0.67	-				-	0.91	1.32
					(5.08)						*(8.29)*	*(3.26)*
$\Delta(M/GDP)_{t-1}$					-0.78	-				-	-1.02	-
					(-4.38)						(-7.47)	
ΔRER	0.18	-	-	-	-	-	-	-0.10	-	-	-	-
	(3.37)							*(-3.82)*				
ΔRER_{t-1}	-	-	-	-	0.20	-	0.14	-	-	-	0.29	-
					(3.68)		*(2.91)*				*(6.74)*	
$\Delta g(GDP_{USA})$	0.38	-	-	-0.08	0.47	-	-	-0.27	0.22	-	0.60	-
	(4.82)			*(-2.20)*	*(5.19)*			*(-6.50)*	*(2.82)*		*(7.62)*	
$\Delta g(GDP_{USA})_{t-1}$	0.47	-	0.33	-	0.49	-	0.38	-	0.36	-	0.47	-
	(7.07)		*(4.12)*		*(6.04)*		*(7.00)*		*(5.28)*		*(6.66)*	
$\mathbf{ecm_{1t-1}}$	**-2.37**	**0.39**					**-1.96**	**0.29**				
	(-11.3)	*(4.05)*					*(-11.8)*	*(3.30)*				
$\mathbf{ecm_{2t-1}}$			**-2.54**	**0.88**					**-2.19**	**0.50**		
			(-7.63)	*(5.78)*					*(-10.4)*	*(5.04)*		
$\mathbf{ecm_{3t-1}}$					**-2.55**	**-1.70**					**-2.95**	**-0.70**
					(-17.4)	*(2.77)*					*(-20.3)*	*(-2.79)*
Restrictions	$\chi^2(20)=26.713$ (0.1435)		$\chi^2(21)=27.365$ (0.1591)		$\chi^2(22)=19.834$ (0.5934)		$\chi^2(19)=29.310$ (0.0613)		$\chi^2(23)=28.262$ (0.2060)		$\chi^2(21)=29.070$ (0.1123)	

Table B1: Short-Run Dynamics (Cont.)
C) TFP Models

	Initial Models						Models with Human Capital					
	Trade		Exports		Imports		Trade		Exports		Imports	
Variables	Δg(TFP)	Δg(K)	Δg(TFP)	Δg(K)	Δg(TFP)	Δg(K)	Δg(TFP)	Δg(K)	Δg(TFP)	Δg(K)	Δg(TFP)	Δg(K)
$\Delta g(TFP)_{t-1}$	0.24		0.23		0.15		0.23		0.23			
	(3.28)		*(2.50)*		*(2.44)*		*(2.45)*		*(2.53)*			
$\Delta g(K)_t$									-0.79		-0.75	
									(-4.47)		*(-4.21)*	
$\Delta g(K)_{t-1}$				-0.37			-0.85					
				(-2.76)			*(-4.00)*					
ΔHC								0.10	-0.24		-0.12	
								(2.97)	*(-4.63)*		*(-2.63)*	
ΔHC_{t-1}							0.27				0.21	
							(2.81)				*(3.52)*	
ΔR&D	0.19	0.06	0.21	0.04	0.20	0.06	0.17	0.05	0.17	0.05	0.18	0.05
	(8.08)	*(3.50)*	*(7.16)*	*(3.09)*	*(10.6)*	*(3.45)*	*(5.62)*	*(3.29)*	*(5.79)*	*(3.03)*	*(8.51)*	*(3.20)*
$\Delta R\&D_{t-1}$	0.11		0.08		0.10		0.12		0.07		0.13	
	(4.32)		*(2.93)*		*(4.31)*		*(4.39)*		*(3.16)*		*(5.49)*	
Δ(T/GDP)	0.30											
	(2.70)											
$\Delta(T/GDP)_{t-1}$		0.21										
		(2.62)										
$\Delta(X/GDP)_t$			1.09									
			(6.34)									
$\Delta(X/GDP)_{t-1}$												
$\Delta(M/GDP)_t$					0.81						0.58	
					(4.42)						*(3.31)*	
$\Delta(M/GDP)_{t-1}$					-0.99						-0.86	
					(-5.99)						*(-5.40)*	
ΔRER	0.24				0.17		0.74		0.64		0.37	
	(3.15)				*(2.68)*		*(9.07)*		*(5.51)*		*(5.30)*	
ΔRER_{t-1}												
$\Delta g(GDP_{USA})$	0.28						0.69		0.89		0.23	
	(2.39)						*(4.94)*		*(6.21)*		*(2.25)*	
$\Delta g(GDP_{USA})_{t-1}$	0.32		0.29		0.24		0.28		0.54		0.16	
	(3.30)		*(2.58)*		*(2.55)*		*(2.49)*		*(5.28)*		*(1.82)*	
$\mathbf{ecm_{1t-1}}$	**-1.87**	**0.17**					**-2.80**	**0.44**				
	(-11.9)	*(2.20)*					*(-6.70)*	*(2.83)*				
$\mathbf{ecm_{2t-1}}$			**-1.97**	**0.41**					**-2.50**	**0.38**		
			(-8.78)	*(4.08)*					*(-7.37)*	*(3.04)*		
$\mathbf{ecm_{3t-1}}$					**-2.54**	**0.20**					**-1.86**	**0.20**
					(-13.7)	*(1.86)*					*(-10.4)*	*(1.91)*
Restrictions	$\chi^2(21)$= 21.862 (0.4075)		$\chi^2(18)$= 26.722 (0.2220)		$\chi^2(20)$=23.212 (0.2785)		$\chi^2(23)$= 33.418 (0.0741)		$\chi^2(22)$= 29.224 (0.1386)		$\chi^2(21)$= 33.162 (0.0510)	

Appendix C: Determination of the Rank and Roots of Companion Matrix[36]

Table C1 GDP Model with Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.76	75.00	71.68	45.68	0.000	0.000
1	1	0.47	22.88	22.61	23.70	**0.064**	**0.068**

Note: In all tables (*) corresponds to the trace test with Bartlett's correction. The asymptotic distributions have been simulated for the current deterministic specifications in all models using CATS for RATS.

	H(0)	H(1)	H(2)
Root1	1	1	0.76
Root2	1	**0.74**	0.76
Root3	0.58	0.74	0.70
Root4	0.58	0.49	0.67

Table C2 GDP Model with Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.64	56.51	53.93	46.25	0.004	0.008
1	1	0.42	19.63	19.47	23.43	**0.142**	**0.148**

	H(0)	H(1)	H(2)
Root1	1	1	0.77
Root2	1	**0.68**	0.66
Root3	0.53	0.68	0.66
Root4	0.53	0.20	0.41

Table C3 GDP Model with Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.85	96.82	92.52	45.86	0.000	0.000
1	1	0.53	27.79	27.30	23.48	0.015	0.018

	H(0)	H(1)	H(2)
Root1	1	1	0.74
Root2	1	**0.69**	0.66
Root3	0.53	0.69	0.66
Root4	0.53	0.31	0.57

Table C4 GDP Model with Human Capital and Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.893	109.416	105.039	50.627	0.000	0.000
1	1	0.552	28.876	28.153	26.247	0.023	0.028

	H(0)	H(1)	H(2)
Root1	1	1	0.70
Root2	1	**0.66**	0.70
Root3	0.61	0.66	0.60
Root4	0.61	0.20	0.20

[36] We have accepted one cointegrated vector for all models estimated, although some rank tests reject the null, given that if we allow r = 2, this second long-run relationship is not stationary. In addition, in order to select the rank of the long-run matrix, it is possible to check additional information such as the graphics of cointegrated vectors, which clearly show that one stationary relationship in this VAR model exists, while the others are not stationary.

Table C5 GDP Model with Human Capital and Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.795	81.932	78.660	50.432	0.000	0.000
1	1	0.498	24.814	24.203	26.855	**0.074**	**0.087**

	H(0)	H(1)	H(2)
Root1	1	1	0.73
Root2	1	**0.70**	0.73
Root3	0.61	0.70	0.63
Root4	0.61	0.03	0.01

Table C6 GDP Model with Human Capital and Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.899	117.567	112.963	50.163	0.000	0.000
1	1	0.621	34.940	34.069	25.681	0.003	0.004

	H(0)	H(1)	H(2)
Root1	1	1	0.68
Root2	1	**0.64**	0.66
Root3	0.62	0.64	0.66
Root4	0.62	0.32	0.43

Table C7 Labour Productivity Model with Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.92	122.66	117.54	56.50	0.000	0.000
1	1	0.53	27.88	27.19	28.74	**0.066**	**0.078**

	H(0)	H(1)	H(2)
Root1	1	1	0.71
Root2	1	**0.69**	0.71
Root3	0.57	0.69	0.68
Root4	0.57	0.51	0.76

Table C8 Labour Productivity Model with Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.89	105.41	101.02	54.47	0.000	0.000
1	1	0.49	24.21	23.84	27.80	**0.135**	**0.147**

	H(0)	H(1)	H(2)
Root1	1	1	0.70
Root2	1	**0.68**	0.70
Root3	0.57	0.68	0.68
Root4	0.57	0.57	0.63

Table C9 Labour Productivity Model with Imports-to- GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.90	123.30	111.85	45.73	0.000	0.000
1	1	0.64	37.53	35.48	23.51	**0.000**	**0.001**

	H(0)	H(1)	H(2)
Root1	1	1	0.84
Root2	1	**0.68**	0.84
Root3	0.21	0.68	0.46
Root4	0.03	0.01	0.11

Table C10 Labour Productivity Model with Human Capital and Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.83	94.22	90.03	50.86	0.000	0.000
1	1	0.55	29.16	28.41	26.13	0.021	0.026

	H(0)	H(1)	H(2)
Root1	1	1	0.62
Root2	1	**0.49**	0.56
Root3	0.55	0.49	0.56
Root4	0.55	0.32	0.29

Table C11 Labour Productivity Model with Human Capital and Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.89	117.60	112.99	60.38	0.000	0.000
1	1	0.64	36.80	35.88	31.12	0.011	0.015

	H(0)	H(1)	H(2)
Root1	1	1	0.75
Root2	1	**0.74**	0.71
Root3	0.63	0.74	0.71
Root4	0.63	0.13	0.34

Table C12 Labour Productivity Model with Human Capital and Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.90	95.43	87.99	50.21	0.000	0.000
1	1	0.22	9.17	8.70	26.11	**0.915**	**0.933**

	H(0)	H(1)	H(2)
Root1	1	1	0.86
Root2	1	**0.59**	0.61
Root3	0.13	0.59	0.61
Root4	0.01	0.05	0.14

Table C13 TFP Model with Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.90	116.57	111.44	54.45	0.000	0.000
1	1	0.53	28.40	27.87	28.32	**0.050**	**0.057**

	H(0)	H(1)	H(2)
Root1	1	1	0.70
Root2	1	**0.68**	0.67
Root3	0.54	0.68	0.67
Root4	0.54	0.39	0.57

Table C14 TFP Model with Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.898	109.130	104.543	54.117	0.000	0.000
1	1	0.487	24.683	24.343	28.244	**0.122**	**0.132**

	H(0)	H(1)	H(2)
Root1	1	1	0.68
Root2	1	**0.68**	0.68
Root3	0.56	0.68	0.67
Root4	0.56	0.54	0.60

Table C15 TFP Model with Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.894	117.82	112.72	54.45	0.000	0.000
1	1	0.610	34.79	34.18	28.32	**0.008**	**0.009**

	H(0)	H(1)	H(2)
Root1	1	1	0.78
Root2	1	**0.62**	0.58
Root3	0.54	0.62	0.56
Root4	0.54	0.24	0.56

Table C16 TFP with Human Capital and Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.941	137.62	131.81	58.34	0.000	0.000
1	1	0.592	33.18	32.22	30.93	**0.024**	**0.031**

	H(0)	H(1)	H(2)
Root1	1	1	0.67
Root2	1	**0.71**	0.67
Root3	0.61	0.71	0.66
Root4	0.61	0.06	0.28

Table C17 TFP with Human Capital and Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.910	125.21	120.06	57.99	0.000	0.000
1	1	0.624	36.16	35.29	29.85	**0.008**	**0.011**

	H(0)	H(1)	H(2)
Root1	1	1	0.80
Root2	1	**0.75**	0.73
Root3	0.61	0.75	0.73
Root4	0.61	0.10	0.28

Table C18 TFP with Human Capital and Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.936	137.20	131.41	58.26	0.000	0.000
1	1	0.618	35.60	34.46	31.04	**0.015**	**0.020**

	H(0)	H(1)	H(2)
Root1	1	1	0.74
Root2	1	**0.64**	0.64
Root3	0.60	0.64	0.64
Root4	0.60	0.25	0.25