

# Equipment Investment, Output and Productivity in China<sup>1</sup>

*(First Draft, please do not quote without permission)*

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## Abstract

The objective of this paper is threefold. Firstly, we provide evidence of the role played by equipment investment as determinant of output and labor productivity in China for the period 1962-2004. Secondly, we assess its robustness in allowing for other relevant sources of economic growth, and finally, we analyze the role played by these different factors on long-run growth. For this purpose we focused our analysis on two factors that have apparently played a relevant role in accounting for China's growth, namely, equipment investment and exports. However, knowing the close relationships that exist between equipment investments with other variables, we have included R&D expenditure, human capital and infrastructures in our analysis. We start up our study exploring the link among equipment investment, R&D expenditure, exports and the real exchange rate as main determinants of labor productivity and output in the short and long-run, that is, our base model. Afterwards, we included human capital and infrastructures in our augmented model. Given the potential interdependence and endogeneity of the variables considered, we employed as statistical framework for analysis the cointegrated VAR model. Our results provide evidence that equipment investment and exports are one of the most important determinants of both labor productivity and output in the long-run even controlling with other sources of growth in China. Furthermore, when human capital is included, we found that it positively affects economic activity in the long-run. In addition, when infrastructures are considered, we proved that have contributed on labor productivity and output in the long-run. Finally, our findings provide robust evidence that R&D expenditure enhances equipment investment on the long-run growth.

**Key words:** Growth, Equipment Investment, Infrastructure, Exports, Human Capital

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## 1 Introduction

At the beginning of the nineties J. Bradford De Long and Lawrence H. Summers highlighted in a series of influential papers that there were good reasons and quantitative evidence in supporting the point of view that machinery and equipment investment might be strongly associated with economic growth. Specifically, they found “those countries with high equipment investment grew extremely rapidly, even controlling for a number of other factors” (De Long and Summers, 1992, p.158). They identified at least three arguments that support their view. Firstly, historical accounts of economic growth invariably assign a central role to mechanization. Secondly, discussions of economic growth in development economies and the new growth theory traditions highlight external economies as an important cause of growth. In addition, given that the equipment sector is one of the most intensive in research and development, it is reasonable to believe that it could be a source of external economies. Thirdly, countries that pursue a government-led “development state” approach to development, seems to have higher equipment investment rates, lower equipment prices, and enjoy of faster economic growth (De Long and Summer, 1991, pp.447-448).

From our point of view, if this association is correct, then the rapid growth in China and its enormous investment effort over recent decades constitutes an interesting case of study and a “natural” laboratory to analyze the role of equipment investment in its recent economic performance. First, because the fast growth experimented by the Chinese economy is unquestionable that can be considered of the type government-led “development state” approach to development. The underlying idea is that countries which adopt more efficient mechanisms to allocate their resources are more likely to grow than those that have a structure similar to poorer economies. The Chinese government initiated gradually the economic reforms to reach a market-oriented economy and launched the industrialization process by transforming the main and more strategic economic sectors in the sixties until the present-day, given the fail of the Great Leap Forward in the fifties. It is plausible to believe that a more liberalized economy, allocates the economic resources and implements the appropriated economic policies more efficiently, enjoying of faster growth.

Secondly, China has undergone high investment rates in recent decades, with a significant contribution of equipment investment as opposed to other components of capital accumulation such as infrastructures which experienced a rapid growth, with massive investment projects, during the pre-reform period. Nevertheless, infrastructures displayed a modest growth since the open-door policy in China given the decrease in new investment in infrastructures and because of the more efficient use of the current transport system since the spectacular increase in the demand of such goods.

Thirdly, although imports in equipment have been one of the strategies of China’s development since the sixties, a change in the sources of provisioning from Soviet block and East European countries to occidental economies with a higher degree of development took place after the fail of the Great Leap Forward. Firstly from Japan, that is, one of the most significant providers in equipment investment since the sixties until the present-day, and after that, the trade partners was progressively diversified to some countries that currently belong to the EU and US. These types of capital goods, especially in equipment, are intensive in R&D and are potential generators of the spillovers or external economies mentioned by De Long and Summers which could be one of the stronger causes of economic growth.

In addition to these arguments, and from a theoretical point of view, the recent endogenous growth literature, especially in the initial “AK” and more recently the Schumpeterian version of the endogenous growth theory, provide formal support to the existence of long-term relationship between investment and growth, running from investment to output and productivity. In this sense, capital accumulation could be a source of economic growth if embodied technological

progress exists, that is, whether among the determinants of capital accumulation predominate the supply factors (Madsen, 2002). Besides, Howitt and Aghion (1998, p. 112) argued that “capital accumulation and knowledge can determine the level of output in the long-run, being both factors complementary processes and playing a significant role on economic growth. In fact, capital accumulation could be a source of long-run growth only if it has followed by technological progress given the diminishing returns on capital accumulation. Alternatively, technological progress can not be sustained indefinitely without the accumulation of capital to be used in the R&D process which creates innovations and in the production process that implements them”.

The empirical evidence in the relationship between equipment investment and economic growth has been widely studied with mixed results. As De Long and Summers (1991, 1992) have already indicated, equipment investment was seen to positively affect productivity growth. Similar results were found by Levine and Renelt (1992). On the contrary however, Auerbach et al. (1994) argued that the results of De Long and Summers (1992) exaggerate the social returns to equipment investment. They used the data set of De Long and Summers and found that if Botswana was removed from the sample the effect of equipment investment on economic growth was consistent with the predictions of the traditional model. In addition, Dellas and Koubi (2001) argued that De Long and Summers missed the social capabilities that are crucial for poor countries to benefit through industrialization. These authors found that industrial employment is more determining than equipment investment in the development process of low-moderate income countries. Finally, Griliches and Jogerson (1966), Hulten (1992) and Greenwood et al. (1997) found evidence that embodied technological change positively affects to long-run productivity. Conversely, Berglas (1965) found no evidence of embodied technological progress and supported the Solow type model.

The evidence in the relation between equipment investment and economic growth to our knowledge is non existent for China. Nonetheless, the majority of the studies found that capital accumulation is one of the determinants of long-run growth in China (Kwan et al., 1999; Yu, 1998; Chow, 1993; Yusuf, 1994).

Although the significant contribution of equipment investment on the economic activity in China seems undeniable given its high growth rates, there are additional factors that could promote output and labor productivity in the steady state (human capital, R&D expenditure, openness and infrastructures). Human capital, as measure of skill of the population, plays a crucial role in improving the productivity of workforce and in its capacity of absorbing or adapting the spillovers of foreign technology.<sup>2</sup> Although countries encourage technology imitation through intermediates or capital imports and foreign direct investment, it is the learning effect which limits its own technology absorptive capability (Borensztein et al., 1998 and Hendricks, 2000). In addition, the degree of openness, especially exports, has substantial benefits on labor productivity and output in the long-run.<sup>3</sup> Firstly, foreign trade is one of the most important conduits for the transmission of the foreign technology.<sup>4</sup> Secondly, competitive pressure made by foreign firms enhances domestic firms to invest in R&D expenditure to survive in the international market, being more efficient and stimulating productivity (Melitz, 2003). Lastly, access to a greater market may create gains through economies of scale (Helpman and Krugman, 1985). On the other hand, the innovations measured by R&D expenditure and investments are closely related and should be complementary to boost labor productivity and output in the long-run (Howitt and Aghion, 1998; Howitt, 2000). To conclude, non-equipment investment such as productive infrastructure, for example railways and highways, is also

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<sup>2</sup> See for example Romer (1990), Young (1991) and Barro (2001)

<sup>3</sup> See Rodrik, (1999) and Rodriguez and Rodrik (2000), who are skeptical about the positive effects of openness on economic growth.

<sup>4</sup> See Young (1991), Chuang (1998), Clerides et al. (1998) and Aw et al. (2000)

considered an additional factor of long-run growth Aschauer (1988, 1989). The improvement in the endowment of infrastructures could enhance the productivity of existing resources through the positive externalities that creates. In addition it could stimulate the increase of other types of investment, given the improvement of the profitability of investment projects due to reduced cost or to improved accessibility to other markets.<sup>5</sup>

There is immense empirical evidence on the relationship between trade or infrastructure and economic growth with mixed results in the literature and China is no exception.<sup>6</sup> Trade, especially exports, has played a relevant role in the Chinese development (Shan and Sun, 1998; Siebert, 2007). In many cases the direction of the causality is bidirectional between exports and output or labor productivity. Nonetheless, Hsiao and Hsiao (2006) found that exports do not cause output. On the other hand, Démurger (2001) found that transport facilities are a key differentiating factor in explaining the growth gap and point to the role of telecommunication in reducing the burden of isolation. On the other hand, Fan and Zhang (2004) found that rural infrastructure and education play a more important role in explaining the difference in rural non-farm productivity than agricultural productivity.

In this context the aim of this paper is threefold. Firstly, we provide evidence of the role played by equipment investment as determinant of output and labor productivity in China for the period 1962-2004. Secondly, we assess its robustness in allowing for other relevant sources of economic growth, and finally, we analyze the role played by these different factors on long-run growth. For this purpose we focused our analysis on two factors that have apparently played a relevant role in account for China's growth, namely, equipment investment and exports. However, as we are aware of the close relationships between equipment investments with other relevant variables for growth we have included R&D expenditure, human capital and infrastructures in our analysis. We start up our study exploring the link among equipment investment, R&D expenditure, exports, and the real exchange rate as the main determinants of labor productivity and output in the short and long-run, that is, our base model. After that, we included human capital and infrastructures in our augmented model given the strong relationship of these variables with equipment investment as factors to promote labor productivity and output in the long-run. Besides our paper attempts to clarify the role played by technological progress in the growth process. From a methodological point of view, we employed the as statistical framework for the analysis the cointegrated VAR model, given the potential interdependence and endogeneity of the variables considered. Our results provide evidence that equipment investment and exports are one of the most important determinants of both labor productivity and output in the long-run even controlling with other sources of growth in China. Furthermore, when human capital is included, we found that it positively affects economic activity in the long-run. In addition, when infrastructures are considered, we proved that have contributed on labor productivity and output in the long-run. Finally, our findings provide robust evidence that R&D expenditure enhances equipment investment on the long-run growth.

This paper contributes to the empirical literature in the following aspects. Firstly and to the best of our knowledge, there is no evidence of equipment investment and its main related variables as sources of economic growth for the case of China. Moreover our point of view emphasizes in the embodied technological progress on equipment investment jointly with the role played among other important factors such as human capital, infrastructures, R&D expenditure and exports as determinants of both labor productivity and output in the long-run in the Chinese economy. In addition, our methodology the cointegrated VAR model avoid the endogeneity problem as it is based on a joint modeling of our variables analyzed, where the

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<sup>5</sup> See for example Munnell (1992), Gramlich (1994), Fernald, (1999), Röller and Waverman (2001), Perkins et al. (2005), Fourie, (2006), and Hulten et al. (2006).

<sup>6</sup> See for example Baldwin (2003), Munnell (1990), Rodrik, (1999), Rodriguez and Rodrik (2000), Holtz-Eakin (1994) and Garcia-Mila et al. (1996) among others.

exogeneity or endogeneity of our variables is examined and where certain restrictions are imposed until the most irreducible form is reached. Finally, this methodology allows us to distinguish between the short and long run effects.

The rest of the paper is set out as follows. Section 2 contains the description of the variables considered and the methodology. Section 3 the empirical results are presented and Section 4 includes the conclusions drawn.

### 3. Data and Methodology

In the empirical analysis we employed annual data from the Chinese economy from 1962 to 2004. Our data set alternatively consists of GDP (*lgdp*) and labor productivity<sup>7</sup> – output per worker- (*lprod*), jointly with net equipment investment (*lifeq*), R&D expenditure<sup>8</sup> (*lrd*), export-to-GDP ratio – exports in FOB terms – (*xgdp*), the real exchange rate (*lrer*),<sup>9</sup> the increases of human capital ( $\Delta hc$ ) and two measures of infrastructures (*lrprail* and *lrphigh*); all the variables are in real terms<sup>10</sup> and in logs (except the ratio of exports to GDP and the increases of human capital). Our basic data source was the National Bureau of Statistics of China (NBS), except for equipment investment and human capital. We took the equipment investment variable from Holz (2006) who made a precise effort to obtain a measure of the capital stock based on the data of investment in fixed assets from the NBS.<sup>11</sup> Besides, we took human capital, (*hc*) – years of schooling- from Wang and Yao (2003) and we extended this data to 2004 making a small variation in the construction of the variable<sup>12</sup>. Finally, we employed two measures in those models in which we introduced infrastructures, firstly the number of passengers-Km of railways (100 million people passenger-km) – *lrprail*- and secondly the number of passenger- Km of highways (100 million people passenger-km) – *lrphigh*-. Thus, we considered not only infrastructure investment but also the demand of infrastructures

The objective has been to provide evidence of the role played by equipment investment as determinant of output and labor productivity in China, of its robustness in allowing for other relevant sources of economic growth, and finally, to analyze the role played by these different factors of long-run growth.

As a statistical framework for analysis, and given the potential interdependence and endogeneity of the variables considered, we used the cointegrated VAR model proposed by Johansen (1988), Johansen and Juselius (1990), Johansen and Juselius (1994) and Johansen (1995) as the most convenient methodology for the description of our macroeconomic time series data. One of the advantages of this methodology is the possibility of combining long-run and short-run information in the data by exploiting the cointegration property (Juselius, 2007). Besides, researchers do not impose any restrictions prior to starting the analysis with regard to the exogeneity or endogeneity of our variables considered. Thus we allow that the data to reveal the nature and interactions among them given the complex relationship that exists from an economic point of view.

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<sup>7</sup> In this paper labor productivity and human capital were corrected by applying the methodology suggested by Nielsen (2004).

<sup>8</sup> We took Total expenditure on scientific research from NBS as proxy variable of R&D expenditure.

<sup>9</sup> The real exchange rate has been calculated using the nominal exchange rate between the Chinese currency and the US \$ (Renminbi/\$) and the respective consumer price indices (CPIs).

<sup>10</sup> We have deflated R&D expenditure with the GDP deflator.

<sup>11</sup> See Holz (2006) for further details on depreciation and deflators.

<sup>12</sup> See Appendix for further details.

In particular, we start with an unrestricted VAR model, a restricted linear trend in the cointegration space and an unrestricted constant ( $\mu$ ) of dimension  $r \times 1$ :

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

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

Where  $X_t$  is the vector of potentially endogenous variables in the different models that we go on to specify;  $\alpha$  and  $\beta$  are matrices of dimension  $p \times r$ ;  $\alpha$  denotes the direction and speed of adjustment toward equilibrium and  $\beta'$  are the matrix of the cointegrated vectors.  $D_{st}$  is the restricted matrix of the level-shift dummies and  $(\Gamma_i, \theta_i, \varphi)$  are the coefficients of the unrestricted matrix in the short run and dummies respectively. Besides, the data are distinctly trending and we need to allow for linear trends in the cointegration relationships when testing for the cointegration rank. Finally, we assumed that the error term,  $\varepsilon_t$ , is an i.i.d. Gaussian sequence  $N(0, \Omega)$  and the initial values,  $X_{k+1}, \dots, X_0$ , are fixed.

Given that the analysis of a system containing a larger number of potentially endogenous variables is econometrically very demanding, as in Juselius and MacDonald (2000 and 2004), a specific-to-general approach in the choice of variables will be adopted. Initially, we start the analysis with a five-dimensional system that include that alternatively includes the GDP or labor productivity, jointly with net equipment investment, R&D expenditure, export-to-GDP ratio, and the real exchange rate (the base model). Then we extended it by the inclusion of human capital and two measures of infrastructures.

The stationary property of our variables is explored with two traditional unit root tests as seen in the Appendix. We concluded that the best characterization of our stochastic process is to accept that all variables are integrated of order one, except human capital, which is integrated of order two. In this last case, we transformed the variable in the first differences to employ the cointegrated VAR model methodology.

Given the significant economic changes in the Chinese economy throughout the period under study we have included two level shifts<sup>13</sup> which are restricted to the cointegration space to guarantee a reasonable stability of the parameters estimated in the concentrated model. The first level shift was introduced in 1970,  $D_{s70}$ , while the second level shift,  $D_{s85}$ , was introduced in 1985. Besides, we have introduced two unrestricted permanent dummies, one for the year 1976,  $dum_{76p}$  and another for 1989,  $dum_{89p}$ . The level shift dummy restricted to the cointegration space in 1970 and the permanent dummy in 1976 attempt to capture the economic consequences since the Cultural Revolution. The explanation of the second level shift corresponds to the slowdown in the output and labor productivity growth rates at the end of second half of the eighties, following the unprecedented trade deficit of 1985. Finally, the dummy in 1989 likely corresponds to the reforms to control the high inflation rate at the end of the eighties and to the decrease in external financing given the events which took place in *Tiananmen Square* in that year.

In all models estimated with two lags is enough to avoid the autocorrelation problems and to capture the dynamics effects following the Hanan and Quinn and Schwarz criterion. In all the cases only output, labor productivity and equipment investment are endogenous in their respective models.<sup>14</sup> In addition, the rank determination test and the roots of companion matrix

<sup>13</sup> The level shift takes the form of (0,0,0,1,1) and the permanent dummy (0,0,1,0,0).

<sup>14</sup> See Table A2 in the Appendix

allow us to detect two long-run relationships in all our estimated models.<sup>15</sup>

#### 4. Empirical Results

Our results are presented in Tables 1-3; panel A of the tables is concerned with the long run relationships between the variables considered in each model, that is, the cointegrated vectors, and panel B shows the short run dynamics.

In Table 1 we present the coefficients estimated for the base models. Panel A describes how equipment investment, exports-to-GDP ratio and the real exchange rate account for labor productivity and output levels. The direction of the causality<sup>16</sup> run from equipment investment, exports and real exchange rate to output and labor productivity in the long-run. On the other hand, the second cointegrated vector shows a significant and positive impact of R&D expenditure on equipment investment. All restrictions<sup>17</sup> imposed on these long-run relationships were accepted with a p-value of 0.097 for the productivity model and 0.617 and the output models respectively. Furthermore and in accordance with the battery of the stability tests<sup>18</sup>, the concentrated model version seems reasonable stable. All coefficients show the expected signs and are significant.

Our findings are consistent with De Long and Summers (1991 and 1992), who argued that equipment investment is the main factor to promote output and labor productivity in the long-run among the components of investment and stressed the probable link between embodied technology and capital goods. It is only possible to find, this long-run effect, when the supply factors predominate among the determinants of investment such as technical changes. Chinese strategy has focused on the promotion of capital and intermediate goods imports for those production processes which are not possible to be produced themselves. It is expected that an embodied technological progress exists in these types of goods, which are imported from developed countries, and that it would be relatively cheaper, thus boosting both capital accumulation and its efficiency.<sup>19</sup>

An interesting result is that R&D expenditure stimulates equipment investment in the long-run in both models. This is consistent with Aghion and Howitt (1998, 1999) and with Howitt (2000) who argued that capital accumulation should be complementary with innovation activities both of which play a significant role in accounting for labor productivity and output in the long-run.

Additionally, and in line with other studies,<sup>20</sup> we found that exports and competitiveness (measured by the real exchange rate) positively affect on labor productivity and output in the long-run. This result is consistent with the export-led growth hypothesis. In fact, exports are exogenous and cause output and labor productivity in the long-run and grew faster than economic activity.<sup>21,22</sup> These effects are related with an economic policy addressed to stimulate

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<sup>15</sup> See Tables A-3 to A-9 in the Appendix

<sup>16</sup> The causality is assessed through significance tests on ECM parameters as it is possible to see in the dynamics of the models estimated.

<sup>17</sup> We have imposed a restriction equal to zero on the coefficients of the variables that are not significant until the most irreducible form is reach. In all cases these restrictions are accepted as it is possible to see in the p-value that we report given that is over 0.05.

<sup>18</sup> Available upon request for all models estimated.

<sup>19</sup> See Lee (1995).

<sup>20</sup> See Shan and Sun (1998), Liu et al (1997 and 2002).

<sup>21</sup> A discussion on export-led growth in China is seen in Bramall (2000).

<sup>22</sup> In the period 1962-1977 exports grew on average at a rate of 8.15%, while the average GDP growth rate was 7.04%. This difference is higher in the post-reform period (1978-2004) with an average growth rate of exports and GDP of 19.54% and 9.52% respectively.

exports with the purpose of enhancing the level of activity and mitigate the foreign exchange constrain, thus making the aforementioned imports policy viable.

Table 1: Base Models: Output and labor productivity

A) Long-Run Relations<sup>23</sup>

		<i>lprod</i>	<i>lgdp</i>	<i>lifeq</i>	<i>lrd</i>	<i>xgdp</i>	<i>lrer</i>
Productivity Model	$\beta'_1$	1		-0.21 [-7.85]	0	-4.79 [-9.45]	-1.11 [-4.95]
	$\beta'_2$	0		1	-1.41 [-13.78]	0	0
GDP Model	$\beta'_1$		1	-0.13 [-2.92]	0	-1.50 [-2.83]	-1.25 [-4.57]
	$\beta'_2$		0	1	-1.39 [-13.99]	0	0

B) Dynamics of the base models

	$\Delta lprod$	$\Delta lifeq$	$\Delta lgdp$	$\Delta lifeq$
$\Delta lprod_{t-1}$	0.33 (4.97)	-		
$\Delta lgdp_{t-1}$			0.34 (6.54)	-
$\Delta lifeq_{t-1}$	-	0.32 (5.35)	-	0.28 (5.65)
$\Delta lrer_{t-1}$	0.14 (2.60)	-	-	-
$\Delta lrd$	0.21 (10.3)	1.91 (9.95)	0.21 (9.05)	1.90 (9.78)
$\Delta lrd_{t-1}$	0.04 (2.41)	-	-	-
$\Delta xgdp$	0.26 (3.13)	-	0.21 (2.72)	-
$\Delta xgdp_{t-1}$	-0.45 (-4.01)	-	-0.18 (-2.16)	-
Constant	-0.56 (-7.35)	-0.54 (-5.03)	1.36 (9.57)	-0.58 (-4.81)
$\Delta D_{s85}$	-	0.29 (3.03)	-	0.26 (3.54)
$\Delta D_{s85t-1}$	-0.03 (-3.31)	-	-0.03 (-3.67)	-
$\Delta D_{s70t-1}$	-0.09 (-4.82)	-0.84 (-4.56)	-0.05 (-2.29)	-0.78 (-4.24)
$dum_{76p}$	-0.07 (-7.43)	-	-0.06 (-7.13)	-
$ecm_1$	<b>-0.59</b> (-7.09)	-	<b>-1.78</b> (-9.80)	-
$ecm_2$	<b>-0.10</b> (-3.89)	<b>-1.24</b> (-4.89)	<b>0.14</b> (3.69)	<b>1.54</b> (4.68)
$\chi^2(16)=16.434$ (0.4231)		$\chi^2(18)=24.092$ (0.1520)		

Note:  $ecm_i = \beta'_i X_t$  + deterministic components and the t-value in brackets.

Table 1.B reports the dynamics of the base models. The labor productivity equation is error-correcting with the two cointegrated vectors found in the productivity model ( $\beta'_1$  and  $\beta'_2$ ). The alpha coefficient of the first long-run relationship,  $ecm_1$ , shows that the adjustment toward equilibrium is approximately a year and a half, while the alpha of the second relationship,  $ecm_2$ , shows that when investment is below its steady state, labor productivity undergoes a slight decrease. In the dynamics we find that labor productivity, R&D expenditure and the real exchange rate positively affect the labor productivity equation, while the net effect of exports is negative in the short-run. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector found in this model. The alpha coefficient

<sup>23</sup> We show only the coefficients of the stochastic variables; the deterministic components are available upon request.

indicates that the adjustment toward equilibrium takes place approximately less than a year. In the short-run, we find that R&D expenditure and the lag of equipment investment have a positive effect on the equation.

The output equation is error-correcting with the first cointegrated vector found in the output model and it adjusts toward equilibrium in almost seven months ( $ecm_1$ ), while output increases when the equipment investment is above its steady state ( $ecm_2$ ). In the dynamics, we find that R&D expenditure and the lag of output have a positive effect on output equation. Besides, the net effect of exports is positive in this equation. On the other hand, equipment investment overreacts with the second cointegrated vector found. As in consequence, we cannot interpret this equation in economic terms.

Table 2: Augmented Models with Human Capital

A) Long-Run Relations

		<i>lprod</i>	<i>lgdp</i>	<i>lfeq</i>	<i>lrd</i>	<i>xgdp</i>	<i>Lrer</i>	$\Delta hc$
Productivity Model	$\beta'_1$	1		-0.17 [-4.27]	0	-4.06 [-5.10]	-1.95 [-6.37]	-0.62 [-2.57]
	$\beta'_2$	0		1	-1.06 [-3.99]	0	0	0
GDP Model	$\beta'_1$		1	-0.25 [-7.65]	0	-2.75 [-3.61]	-2.82 [-9.55]	-0.70 [-3.05]
	$\beta'_2$		0	1	-1.39 [-12.44]	0	0	0

B) Dynamics of Augmented Models with Human Capital

	$\Delta lprod$	$\Delta lfeq$	$\Delta lgdp$	$\Delta lfeq$
$\Delta lprod_{t-1}$	-	-2.82 (-4.31)		
$\Delta lgdp_{t-1}$			-	-1.40 (-2.85)
$\Delta lfeq_{t-1}$	0.09 (6.83)	1.01 (6.93)	0.04 (4.24)	0.55 (6.06)
$\Delta lrer$				-1.16 (-3.85)
$\Delta lrer_{t-1}$		-1.13 (-2.49)		
$\Delta lrd$	0.15 (6.21)	1.33 (6.14)	0.20 (7.87)	1.70 (8.70)
$\Delta^2 hc$	0.09 (2.53)	-		
$\Delta^2 hc_{t-1}$		0.70 (2.24)		1.01 (3.70)
$\Delta xgdp$		-2.24 (-3.35)		
$\Delta xgdp_{t-1}$		2.70 (3.02)	-0.19 (-2.19)	
Constant	-0.42 (-7.08)	-0.13 (-2.19)	0.68 (10.0)	-0.66 (-4.44)
$\Delta D_{s85}$		0.26 (3.31)		0.29 (4.16)
$\Delta D_{s85t-1}$	-0.04 (-4.46)			0.17 (2.49)
$\Delta D_{s70}$	-0.09 (-3.16)	-0.69 (-2.67)		
$\Delta D_{s70t-1}$	-0.09 (-4.28)	-0.95 (-4.94)	-0.05 (-2.30)	-0.84 (-4.49)
$dum_{76p}$	-0.06 (-6.97)		-0.05 (-6.63)	
$ecm_1$	<b>-0.59</b> (-7.36)	-	<b>-0.73</b> (-10.5)	-
$ecm_2$	<b>-0.27</b> (-4.60)	<b>-2.80</b> (-5.69)	<b>-0.33</b> (-4.31)	<b>-3.09</b> (-5.20)
X <sup>2</sup> (16)=22.345 (0.1324)		X <sup>2</sup> (20)=23.142 (0.2819)		

Hereinafter, we address the robustness of our results by including other variables that have been considered prominent determinants of output and productivity in the literature on economic growth (human capital and infrastructures). In addition we explore the role played by these variables together with equipment investment and trade considered until this time.

Human capital has been proxied by per capita years of schooling. The assumption is that more educated people are a good indicator of more skilled and more productive workers. Additionally, it is expected that more skilled people would be more able to innovate, and to also make the absorption and adaptation of the new technology embodied in equipment investment easy.

In Table 2 we present the coefficients estimated for the augmented models with the human capital. The direction of the causality runs from equipment investment, exports, real exchange rate and human capital to output and labor productivity in the long-run. We find two cointegrated vectors for both labor productivity and output models, where all the restrictions were accepted with a p-value of 0.336 and 0.391, respectively. Our long-run relationships are reasonably stable in the concentrated model, and the coefficients are significant with the expected sign.

These findings show that our conclusions on equipment investment and exports as sources of economic growth remain unchanged even for the inclusion of human capital, assessing its robustness. Of course, these same results suggest that investment and exports are not the only determinants of output and productivity in the long-run, but also human capital is a significant factor in determining the steady state of these variables, when equipment investment is considered. This finding is in agreement with, Greenwood et al. (1997), Temple and Voth (1998), Hendricks (2000) and Ortiguera (2003). Thus, output and labor productivity not only depend on equipment investment, but also on the technology absorption or on the adaptation through the worker's skill, and both factors are significant in the rapid Chinese development. Finally and similarly to the previous model estimated, we find that R&D expenditure encourages equipment investment in the long-run, run, but we did not find any direct impact of human capital on equipment investment. Therefore, new technologies open up new economic opportunities for equipment investment to take place in physical capital, and both, physical and human capital, encourage output and productivity.

Table 2.B reports the dynamics of the augmented model with human capital. The labor productivity equation is error-correcting with the two cointegrated vectors found in labor productivity model ( $\beta'_1$  and  $\beta'_2$ ). The alpha coefficient of the first long-run relation,  $ecm_1$ , shows that the adjustment toward equilibrium is a year and a half, while the alpha of the second relationship,  $ecm_2$ , shows a slight and negative effect on the labor productivity equation when equipment investment is below of its steady state. In the dynamics, we found that human capital, R&D expenditure and equipment investment have a positive effect on the labor productivity equation. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector ( $\beta'_2$ ). The alpha coefficient of this long-run relationship,  $ecm_2$ , shows a rapid adjustment toward equilibrium at approximately four months. In the short-run, we find that human capital, R&D expenditure, equipment investment have a positive effect on this equation, while both labor productivity and the real exchange rate have a negative effect. Finally we find a net and positive effect of exports on the equipment investment equation.

The output equation is error-correcting with the two cointegrated vector found ( $\beta'_1$  and  $\beta'_2$ ). The alpha coefficient in the first long-run relationship,  $ecm_1$ , shows that the adjustment toward equilibrium is about nine months, while the second relation,  $ecm_2$ , shows a slight and negative effect on the output equation. In the dynamics we find that equipment investment and R&D expenditure have a positive effect on the output equation, while exports have a negative effect. The equipment investment equation is error-correcting with the second cointegrated vector. The

alpha coefficient shows a rapid adjustment approximately less than three months. In the dynamics we find that equipment investment, R&D expenditure, human capital positively affect the equipment investment equation, while the lags of output and the real exchange rate have a negative effect.

Finally, we will take into account the role of infrastructures in this context. We took two indicators of infrastructure namely, passenger-km of highways and passenger-km of railways. These indicators are convenient given that they are associated with both infrastructure investment and demand. So, we could interpret this variable as a measure of the efficiency of the infrastructure. This issue is relevant in the Chinese economy because, during the pre-reform period, most infrastructure investment projects were finished and more investment was made than required. Since the seventies, however, a vastly demand of transportation system has taken place with a modest increase in new investments in infrastructures, which may only be account for by the more efficient use of the current transportation system.

In Table 3 we present the coefficients estimated for the augmented model with the infrastructures models. All the restrictions in the labor productivity model were accepted with a p-value of 0.05 when *lrprail* is included. The direction of the causality runs from equipment investment, exports and infrastructures to labor productivity in the long-run. However, we found no evidence when *lrphigh* was incorporated into this model. In the output model, all the restrictions were accepted with a p-value of 0.192 and 0.157 respectively, when the *lrprail* and *lrphigh* variables were included. The direction of the causality runs from equipment investment, exports, infrastructures and the real exchange rate<sup>24</sup> to output in the long-run. These long-run relations are reasonably stables in the concentrated model.

As in the case of human capital, when infrastructure is considered, the results obtained initially for exports and investment are maintained. So, even when we control our estimates for other relevant factors, such as human capital and infrastructures, we conclude that equipment investment and foreign trade polices have played a significant role in Chinese development in the last four decades. In addition, we provide evidence that infrastructure<sup>25</sup> enhances both labor productivity and output in the long-run. These findings are consistent with Aschauer (1988, 1989), Munnell (1990), Eisner (1991), Canning et al. (1994), Easterly and Rebelo (1993) and Flores de Frutos and Pereira (1993) to cite but a few. Moreover, an interesting result is that both equipment investment and infrastructure promote labor productivity and output in the long-run, which shows there is some degree of complementary among them. Finally, R & D expenditure continues to be the only non-deterministic factor that stimulates equipment investment in the long run, without being detected any direct influence of infrastructures in that relationship.

Table 3.B describes the dynamics of the augmented model with infrastructures. The labor productivity equation is error-correcting with the two cointegrated vectors found in ( $\beta'_1$  and  $\beta'_2$ ). The alpha coefficient of the first long-run relationship,  $\text{ecm}_1$ , shows a fast adjustment toward equilibrium, at approximately six months, while the alpha of the second cointegrated vector adjusts toward equilibrium when labor productivity is below its steady state. In the dynamics we can observe no evidence of the congestion effect on infrastructure either in the short or long run. We found that infrastructure and equipment investment are significant factors in accounting for labor productivity in the short-run. Besides, R&D expenditure and the real exchange rate have a positive effect on labor productivity, unlike exports which present a net and negative effect on labor productivity.

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<sup>24</sup> The real exchange rate causes output in the long-run only when *lrprail* is considered.

<sup>25</sup> We estimated infrastructures using a number of km of highways and railways. However, we did not find evidence of these infrastructure indicators on labor productivity and output in the long-run. It seems that not only the volume of investment but also the use of this type of investment are relevant. We do not report these estimates, but they are available upon request.

Table 3: Augmented Models with Infrastructures

## A) Long-Run Relations

		<i>lprod</i>	<i>lgdp</i>	<i>lifeq</i>	<i>lrd</i>	<i>xgdp</i>	<i>lrer</i>	<i>lrphigh</i>	<i>lrprail</i>
Productivity Model	$\beta'_{11}$	1		-0.13 [-5.31]	0	-5.94 [-16.26]	0		-0.20 [-4.25]
	$\beta'_{12}$	0		1	-1.40 [-14.73]	0	0		0
GDP Models	$\beta'_{21}$		1	-0.20 [-5.88]	0	-3.98 [-6.39]	-1.04 [-2.80]		-0.45 [-3.61]
	$\beta'_{22}$		0	1	-1.44 [-14.93]	0	0		0
	$\beta'_{31}$		1	-0.18 [-3.33]	0	-4.99 [-8.11]	0	-0.83 [-5.68]	
	$\beta'_{32}$		0	1	-0.89 [-3.35]	0	0	0	

## B) Dynamics of Augmented Models with Infrastructures

	$\Delta lprod$	$\Delta lifeq$	$\Delta lgdp$	$\Delta lifeq$	$\Delta lgdp$	$\Delta lifeq$
$\Delta lprod_{t-1}$	-	-2.36 (-3.67)				
$\Delta lgdp_{t-1}$			-	-2.37 (-4.33)	-0.29 (-2.59)	-1.76 (-2.76)
$\Delta lifeq_{t-1}$	0.04 (3.50)	0.72 (5.56)	0.04 (4.35)	0.64 (6.69)	0.04 (3.53)	0.68 (5.93)
$\Delta lrer$	-	-	-	-1.35 (-3.47)	-0.14 (-2.36)	-
$\Delta lrer_{t-1}$	0.27 (6.00)	-	-	-1.37 (-3.44)	-	-
$\Delta lrd$	0.20 (9.36)	1.78 (8.68)	0.21 (8.55)	1.60 (8.23)	0.23 (9.35)	1.40 (7.12)
$\Delta lrd_{t-1}$	0.05 (3.23)	-	-	-	-	-
$\Delta xgdp$	0.37 (4.76)	-	-	-1.46 (-1.90)	0.56 (4.37)	-
$\Delta xgdp_{t-1}$	-0.75 (-6.30)	-	-0.41 (-3.60)	-	-0.43 (-3.09)	-
$\Delta lrprail$	-	-	-	-		
$\Delta lrprail_{t-1}$	0.12 (5.16)	-	-	-0.81 (-4.23)		
$\Delta lrphigh$					0.27 (6.04)	-
$\Delta lrphigh_{t-1}$					0.26 (5.00)	-
Constant	-0.89 (-8.90)	-0.70 (4.10)	0.77 (7.45)	-0.69 (-4.77)	0.81 (8.11)	-
$\Delta D_{s70}$	-0.05 (-1.95)	-0.41 (-1.68)	-	-	-	-0.37 (-1.80)
$\Delta D_{s70t-1}$	-0.09 (-3.99)	-0.95 (-4.69)	-0.07 (-3.23)	-0.80 (-4.53)	-	-0.74 (-4.84)
$\Delta D_{s85}$	-	0.20 (2.40)	-	0.40 (4.61)	-	-
$\Delta D_{s85t-1}$	-0.04 (-4.81)	-	-0.05 (-5.13)	-	-0.07 (-4.82)	-
$dum_{76p}$	-0.07 (-8.93)	-	-0.07 (-7.57)	-	-	-
$dum_{89p}$	-	-	-	-	-0.03 (-2.58)	-
$ecm_1$	<b>-1.73</b> (-8.79)	-	<b>-3.70</b> (-7.72)	-	<b>-2.25</b> (-7.97)	-
$ecm_2$	<b>-0.08</b> (-3.39)	<b>-1.13</b> (-4.77)	<b>-0.22</b> (-5.09)	<b>-2.35</b> (-6.59)	<b>-0.19</b> (-9.53)	<b>-1.03</b> (-5.25)
X <sup>2</sup> (16)=25.049(0.0690)			X <sup>2</sup> (18)=27.606 (0.0683)			X <sup>2</sup> (16)=24.132(0.0867)

On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector ( $\beta'_2$ ). The alpha coefficient of this second long-run relation,  $ecm_2$ , shows that the adjustment toward equilibrium is approximately every year. In the dynamics, we find that R&D expenditure and the lag of equipment investment have a positive effect on this equation, while labor productivity shows a negative effect.

The first output equation is error-correcting with the two cointegrated vector found in the output model when *lrprail* is considered ( $\beta'_{11}$  and  $\beta'_{12}$ ). The alpha coefficient of the first relation,  $ecm_1$ , shows a rapid adjustment toward equilibrium, while the alpha of the second relation,  $ecm_2$  adjusts toward equilibrium when output is below its steady state. In the dynamics we find that R&D expenditure and equipment investment positively affects on the output equation, while exports have a negative effect in the short-run. On the other hand, the equipment investment equation is error-correcting with the second long-run relationship found ( $\beta'_{12}$ ). The adjustment toward equilibrium is also very rapid. In the dynamics, we can observe that R&D expenditure and the own lag of equipment investment have a positive effect on equipment investment, while infrastructure and exports have a negative effect. Besides, the real exchange rate demonstrates that an increase (depreciation) tends to reduce equipment investment. It is possible to account for this effect given that many equipment and machinery are imported in China, hence depreciation increases the price of imported goods. Finally, the lag of output has a negative effect on the equipment investment equation.

The second output equation is error-correcting with the two cointegrated vectors found in the output model when *lrphigh* is considered ( $\beta'_{21}$  and  $\beta'_{22}$ ). The alpha coefficient of the first relation,  $ecm_1$ , shows an adjustment towards equilibrium at approximately six months. In the dynamics we find that infrastructure, R&D expenditure and equipment investment have a positive effect on output equation, unlike the lag of output and the real exchange rate, which have a negative effect on this equation. Finally, the current value of exports has a positive effect, although its lag has a negative effect. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector found in ( $\beta'_{22}$ ). The adjustment toward equilibrium is approximately a year. In the short-run we found that R&D expenditure and the lag of equipment investment have a positive effect on equipment the investment equation, unlike the lag of output which negatively affects this equation.

## 5 Conclusions

De Long and Summers (1991, 1992) emphasized the strong association of equipment investment and economic growth, especially in the case of developing countries which are not able to produce this type of goods themselves. These countries have to acquire most of their investment in machines and equipment in international trade through imports from advanced and intensive R&D countries. It is expected that embodied technological progress exists in this types of goods and cause long-run growth. Nonetheless, equipment investment is related with other important determinants of output and labor productivity such as human capital, infrastructures, R&D expenditure and openness among others. Human capital is a recurrent determinant of growth in the endogenous growth literature (Young, 1991; Romer, 1990; and Barro, 2001). This literature also has emphasized the substantial benefits from trade activity for example through economies of scale, access to advanced technology or spillovers (Helpman and Krugman, 1985). The expected role of infrastructures on growth changed following the empirical work by Aschauer (1989). Today infrastructures are considered such as a source of externalities that stimulate output and productivity. Besides, the Schumpeterian version in the endogenous growth theory stresses the link between innovation activities and capital accumulation (Aghion and Howitt, 1998; Howitt, 2000). However, the empirical evidence of equipment investment and related variables is mixed; consequently, no conclusive results are

found, especially regarding the direction of the causality of these factors on economic growth.

Our findings suggest that equipment investment and exports are relevant factors to account for output and labor productivity in the long-run, even controlling for other sources of long-run growth in China for the period 1962-2004. Moreover, we found that the direction of the causality in all the models estimated is from equipment investment and exports to output and labor productivity in the long-run. However, when human capital and infrastructures are included we found that these factors have also a positive effect on labor productivity and output, in the long run. A common result in all the models estimated is the positive effect of R&D expenditure on equipment investment in the long-run. Consequently, it seems that both capital accumulation and technical change are significant for growth in the Chinese economy. Firstly, because we found that equipment investment and infrastructure have long-run effects and are likely due the embodied technological progress. Secondly a positive effect of R&D expenditure on equipment investment is more plausible in some Schumpeterian version of endogenous growth theory than in traditional models of growth. Finally, the positive effect of human capital on labor productivity and output in the long-run probably is related with other forms of transmission of technology like absorption, adaptation or new inventions which cause long-run growth.

In short, capital accumulation (physical and human) and exports has played a significant role since 1962-2004 in China. The economic policies made by the government such as investment effort in infrastructures, promotion of equipment investment together with human capital and exports have apparently created the favorable conditions for long-run growth. Nevertheless, it is not sufficient condition to sustain long-run growth because more economic reforms are needed to benefit from balanced growth, not only in the sources of growth, but also among the different regions in the Chinese economy. Regardless of this argument, the Chinese economy currently is one of the most important economies in the world, where the most important aspect is that has successfully changed from a planned economy to a market-economy, with improvements in labor productivity and output.

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## 7 Appendix

Table A1: Unit Roots Tests

Variables	ADF		KPSS	
	const	trend	const	trend
lrprail	-0.84	-1.91	1.47*	0.19***
$\Delta$ lrprail	-4.90*	-4.87*	0.18	0.12
lrphigh	-0.46	-1.36	1.49*	0.17**
$\Delta$ lrphigh	-3.04*	-3.02*	0.18	0.18
lrer	-0.95	-1.40	1.42*	0.16**
$\Delta$ lrer	-3.79	-3.80***	0.12	0.09
lrd	0.08	-3.53	1.40*	0.10
$\Delta$ lrd	-5.86*	-5.88*	0.06	0.06
xgdp	1.49	-1.43	1.41*	0.27*
$\Delta$ xgdp	-4.96*	-5.89*	0.49	0.06
lgdp	0.66	-2.81	1.49*	0.27*
$\Delta$ lgdp	-6.31*	-6.40*	0.07	0.05
lprod	2.53	-1.79	-1.47*	0.34*
$\Delta$ lprod	-4.35*	-5.72*	0.24	0.04
lifeq	-0.69	-6.65*	1.25*	0.03
$\Delta$ lifeq	-8.34*	-8.24*	0.02	0.02
hc	-0.77	-2.64	1.53*	0.24*
$\Delta$ hc	-2.62	-2.64	0.18	0.15**
$\Delta^2$ hc	-4.15*	-4.11*	0.06	0.06

\* Rejection of the null at all the levels sign.

\*\* Rejection at 5% and 10%

\*\*\* Rejection at 1%

Table A2: Weakly Exogeneity Test

Vbles.	Model 1	Model 2	Model 1.1	Model 2.1	Model 1.2	Model 2.2	Model 2.3
lrer	0.06	0.50	0.07	0.05	0.13	0.81	0.64
xgdp	0.32	0.59	0.15	0.27	0.14	0.20	0.41
lrd	0.05	0.20	0.06	0.05	0.27	0.15	0.14
$\Delta$ hc			0.26	0.51			
lrprail					0.06	0.05	
lrphigh							0.06

Model 1: Productivity Base Model

Model 2: Output Base Model

Model 1.1: Productivity Augmented Model with Human Capital

Model 2.1: Output Augmented Model with Human Capital

Model 1.2: Productivity Augmented Model with Infrastructure (rprail)

Model 2.2 Output Augmented Model with Infrastructure (rprail)

Model 2.3: Output Augmented Model with Infrastructure (lrphigh)

Note: LR-Test, Chi-Square ( $\chi^2$ ), P-values

Table A3: Determination Rank Test and the Roots of the Companion Matrix

Productivity Base Model							
p-r	r	Eig. Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.72	79.55	70.53	49.46	0.000	0.000
1	1	0.50	28.07	23.11	25.61	0.024	0.097

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.73</b>
Root2	1	0.77	0.71
Root3	0.47	0.30	0.71
Root4	0.06	0.12	0.16

Table A4: Determination Rank Test and the Roots of the Companion Matrix

Output Base Model							
p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.64	60.19	54.24	40.87	0.000	0.001
1	1	0.38	19.35	17.63	20.81	0.080	0.129

  

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.62</b>
Root2	1	0.59	0.62
Root3	0.34	0.30	0.47
Root4	0.04	0.30	0.47

Table A5: Determination Rank Test and the Roots of the Companion Matrix  
Productivity, Augmented Model with Human Capital

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.72	82.23	72.37	54.28	0.000	0.001
1	1	0.52	30.08	22.08	28.00	0.030	0.212

  

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.67</b>
Root2	1	0.87	0.61
Root3	0.51	0.17	0.61
Root4	0.05	0.08	0.17

Table A6: Determination Rank Test and the Roots of the Companion Matrix  
Output, Augmented Model with Human Capital

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.73	82.96	75.17	53.90	0.000	0.000
1	1	0.52	30.12	23.59	27.41	0.027	0.146

  

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.67</b>
Root2	1	0.84	0.63
Root3	0.31	0.13	0.63
Root4	0.02	0.13	0.02

Table A7: Determination Rank Test and the Roots of the Companion Matrix  
Productivity, Augmented Model with Infrastructure (rprail)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.70	72.16	63.95	43.77	0.000	0.000
1	1	0.45	23.89	20.90	23.00	0.036	0.086

  

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.70</b>
Root2	1	0.67	0.51
Root3	0.47	0.38	0.51
Root4	0.06	0.08	0.07

Table A8: Determination Rank Test and the Roots of the Companion Matrix  
Output, Augmented Model with Infrastructure (rprail)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.66	64.28	58.02	44.59	0.000	0.002
1	1	0.40	20.97	19.38	22.45	0.080	0.123

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.65</b>
Root2	1	0.64	0.43
Root3	0.34	0.14	0.43
Root4	0.01	0.07	0.29

Table A9: Determination Rank Test and the Roots of the Companion Matrix  
Output, Augmented Model with Infrastructure (rphigh)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.79	74.54	68.82	49.92	0.000	0.000
1	1	0.26	12.16	10.75	26.68	0.739	0.827

	H(0)	H(1)	H(2)
Root1	1	1	<b>0.73</b>
Root2	1	0.64	0.73
Root3	0.20	0.51	0.52
Root4	0.20	0.51	0.52

Table A10: Percentage of Equipment and  
Machinery Imported to total Imports (average)

1950s	1960s	1970s	1980s	1990s	2000-2005
51%	20%	22%	25%*	39%	44%

\* Only contains data for the years 1980-1985 and 1989, given the limitation of the data.  
Source: Data from 1950-1984 was taken from Conroy (1986).  
Data since 1985-2005 was taken from the NBS.

## Measure of Human Capital

Human capital was taken from Wang and Yao (2003). These authors obtained a stock of human capital for each level of education as follows:

$$\begin{aligned}
 H_{1,t} &= (1 - \delta_t)H_{1,t-1} + (PRI_t - JUNIOR_{t+3}) \\
 H_{2,t} &= (1 - \delta_t)H_{2,t-1} + (JUNIOR_t - SENIOR_{t+3} - SPECIAL_{t+2}) \\
 H_{3,t} &= (1 - \delta_t)H_{3,t-1} + (SENIOR - HIGH_{t+3,5}) \\
 H_{4,t} &= (1 - \delta_t)H_{4,t-1} + (SPECIAL)_t \\
 H_{5,t} &= (1 - \delta_t)H_{5,t-1} + HIGH_t
 \end{aligned}$$

Where  $H_{ji}$  is the number of graduates with  $j$  the highest level of schooling attained in year  $t$ ,  $j=1$  for primary, 2 for junior secondary, 3 for senior secondary, 4 for specialized secondary, and 5 for tertiary. These authors consider that a person who did not complete the enrolled level  $j$  is considered  $t$  have completed the lower level of schooling ( $j-1$ ). Given that the lengths of different schooling cycles are known the author calculate the net number of graduates at each level of schooling. In addition,  $\delta_t$  is the mortality rate of the population in year  $t$  from the NBS. According with Wang and Yao (2003), the aggregate human capital stock is as follows:

$$H_t = \frac{(5H_{1t} + 8H_{2t} + 11H_{3t} + 10H_{4t} + 14.5H_{5t})}{Pop_t}$$

Where  $pop_t$  is the population in the age group 15-64 in year  $t$ . The initial value is 0.84 in 1951 based in India data of human capital (For further details see Wang and Yao, 2003). These authors cover the period 1952-1999. However the procedure employs futures value of each level of education and they do not hold data for these years. We have modified this measure by calculating a percentage of success for each level of education for the purpose of obtaining the number of graduates for the years that the data are missing in Wang and Yao (2003). We took the data from the NBS which covers the extended period of 1952-2004.