NCER National Centre for Econometric Research

NCER Working Paper Series

Imported Equipment, Human Capital and Economic Growth in Developing Countries.

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Working Paper #16

May 2007

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JEL Classification: F43, O15, O40

Keywords: Capital Goods Imports, Human Capital, Developing Countries, Technology Diffusion

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Abstract

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1. Introduction

Total Factor Productivity (TFP) is driven by the technological knowledge an economy is able to utilize. This knowledge comes in many forms, among them knowledge embedded in machinery and human capital. In a series of papers De Long and Summers (DS) (1991, 1992 and 1993) found that there was a strong causal link between equipment investment and economic growth, confirming the traditional view that the accumulation of machinery is a prime determinant of national rates of productivity growth[1].

There are a number of reasons to expect a relationship between equipment investment and output growth. DS (1991) for example refer to economic history that suggests that many novel technologies were combined in capital goods, suggesting that implementing new technology that raises TFP requires investment in capital equipment. New or endogenous growth theories (for example Romer, 1986; Lucas, 1988) that rely on some kind of externality or spillover to sustain long-run growth also present arguments in favour of a relationship between equipment investment and growth. Two arguments in particular suggest that there may be strong externalities to equipment investment. Firstly, we may expect that investment in equipment that embodies the latest technology is likely to facilitate growth through learning by doing, a process likely to be particularly strong in the highly specialised capital goods industry. Secondly, we may expect that equipment investment encourages technology diffusion. Given the concentration of R&D activity in relatively high-tech industries, such as the capital goods industry, we may expect that the

[1] Jones (1994) reaches a similar conclusion by considering the relationship between equipment prices and growth.

production of capital goods will result in further externalities through technology diffusion which may encourage further innovation.

The results of DS are in contrast to those of the influential study of Mankiw, Romer and Weil (MRW) (1992) who argue that there is no special role for equipment investment and no impact of investment on long-run growth. MRW suggest that international differences in long-run growth rates can be largely explained by a conventional Solow model augmented with human capital. A small number of papers have addressed this apparent contradiction. Auerbach et al (1994) for example question the conclusion of DS that there is a large social return to equipment investment. They show that the returns to investment in equipment (and structures) for a sample of 19 OECD countries are fully consistent with the Solow model. Moreover, excluding potential outliers produces a coefficient on equipment investment not out of line with the Solow model. Temple (1998) responds to the results of Auerbach et al (1994) and finds support for the results of DS, at least for developing economies[2]. Temple (1998) employs an augmented Solow model to control more rigorously than DS for the roles of human capital and labour force growth and shows that for the developing countries in the MRW dataset the returns to equipment investment are high and cannot easily be explained by the Solow model. Moreover, this conclusion holds once measurement error has been controlled for, instrumental variables estimation employed and outliers removed[3].

[2] See also Temple and Voth (1998). De Long and Summers (1994) also present a terse response to the paper of Auerbach et al (1994).
[3] Temple (1998) employs statistical techniques to identify outliers, rather than the ad-hoc approach of Auerbach et al (1994) who simply removed one observation (Botswana) with high rates of equipment investment and high rates of output growth.

In this paper we examine the importance of *imported* machinery for growth in a sample of 55 developing countries over the period 1960-1999[4]. A small number of existing papers consider the relationship between imported equipment and growth in developing countries[5]. Lee (1995) for example develops a model whereby low-income countries by importing relatively cheaper capital goods from high-income countries increase the efficiency of capital, which in turn increases the growth rate of output. Growth rates are higher therefore in developing countries that use imported inputs relatively more than domestically produced inputs for investment. Lee tests his theory by including the ratio of imported to domestic capital goods in a cross-country growth regression for up to 89 countries over the period 1960-1985. The results confirm that there is a positive and significant relationship between the ratio of imports in investment and the growth rate of GDP per capita. Moreover, when the share of imports in GDP is included in the model its coefficient is insignificant, suggesting that it is the composition and not the level of imports that is important for growth. Mazumdar (2001) extends the model of Lee by distinguishing between domestic equipment and non-equipment investment. The paper argues that developing countries that have a comparative disadvantage in the production of machinery (and a comparative advantage in the production of consumer goods) could

[4] Eaton and Kortum (2001) show that world R&D production and world production of capital equipment are concentrated in a small number of advanced countries. Warner (1992) also shows that the bulk of equipment is imported from abroad in all but the very richest economies, with the fraction of imported equipment found to be up to 80% for countries such as Colombia.

[5] This literature is therefore related to at least two alternative strands of empirical literature. Firstly, it relates to the voluminous literature on the relationship between openness and growth. The conventional assumption and the weight of evidence suggests a positive relationship between openness and growth. A more critical view is provided by Rodriguez and Rodrik (2001) who examine recent research on trade policy and growth. This literature is also related to the literature considering the international diffusion of knowledge. While international trade is only one of a number of channels through which such knowledge may diffuse, with FDI and patent data being two others, the strongest evidence of a positive relationship between international knowedge diffusion and growth is found when trade, and imports in particular, is the channel considered. See Coe, Helpman and Hoffmaister (1997) for an early study on international technology diffusion into developing countries and Keller (2004) for a review of the evidence.

benefit from trade in terms of growth through the importation of machinery that is cheaper or of better quality. Mazumdar confirms these predictions using a sample of 30 developing countries and data on five-year averages over the period 1970-1990.

Where our paper differs from those of DS as well as those of Lee (1995) and Mazumdar (2001) is by allowing the relationship between equipment imports and growth to be dependent upon the level of human capital in the importing country. Since all countries have the same access to equipment at similar prices (excluding transport costs and tariffs), differences in economic performance cannot be fully explained by equipment investment alone. As such, there must be reasons why some countries invest more in equipment than others. These reasons may themselves be the main reasons for observed differences in economic performance. Imported equipment can be considered to be particularly important for growth since it affects future production facilities and through knowledge diffusion, imitation and reverse engineering that improves the productivity of domestically produced equipment as well. To make the best use of such embodied knowledge an economy must have the absorptive capacity to be able to absorb the embodied knowledge however. Hence human capital's role in diffusing advanced technology could be an important determinant of the relationship between equipment investment and growth.

There are few studies that consider the importance of complementarities between human capital and equipment investment, notable exceptions being Hendricks (2000) and

Temple and Voth (1998)[6]. Hendricks (2000) develops a model that allows for complementarities between technology embodied in capital goods and skills embodied in workers. Productivity is assumed to depend not only on the technology embodied in capital goods, but also on how well this technology matches the level of worker skills. Calibrating his model to US data he finds that the results suggest that the model can adequately account for the observed empirical relationships between growth rates, equipment investment shares and relative equipment prices[7]. Temple and Voth (1998) on the other hand find when splitting their sample of countries based on secondary enrolment ratios that the coefficient on equipment investment falls as enrolment ratios increase, suggesting that higher levels of human capital may reduce the benefits of equipment investment. They argue that the reason for this is that countries with higher levels of human capital are more industrialised and thus have less scope for structural change, which they argue is the key driver of equipment investment[8].

The approach we adopt is to consider imports of machinery and transport equipment from the OECD as our measure of investment in (imported) equipment and examine how this

[6] The literature on the role of human capital more generally for growth and its role in knowledge diffusion is more substantial. Interestingly, many studies find either no relationship or a negative relationship between measures of human capital and growth (see for example Benhabib and Spiegel, 1994; Pritchett, 2001). A role for human capital in the diffusion of disembodied knowledge has been found by Benhabib and Spiegel (1994), while Benhabib and Spiegel (2005) find that there is some level of human capital below which country's TFP levels would fall farther behind the leader. With regards to embodied spillovers Coe, Helpman and Hoffmaister (1997) and Engelbrecht (2002) finds little role for human capital in affecting the extent of international R&D spillovers, though Falvey et al (2007) find that countries with higher levels of human capital benefit more from international R&D spillovers.

[7] Eaton and Kortum (2001) also argue that a country's level of human capital may provide some indication of its ability to exploit foreign technology. They then show that their estimates of barriers to capital goods imports are lower in countries with higher average years of schooling, suggesting that the benefits of imported equipment may increase with the level of human capital.

[8] Navaretti et al (2000) also present evidence in support of the hypothesis that the absorptive capacity of a country can affect the choice of both the type and vintage of machines invested in. They conclude that investing in education is likely to improve the overall investment environment and increase a country's ability to absorb new technologies.

variable impacts upon growth. The use of data on imported machinery and equipment is justified by noting that DS (1993) suggest that the best predictor of equipment investment in their sample was the share of equipment imports in GDP, which moves one-for-one with their 1991 estimates of national equipment investment rates. We examine the relationship between imported equipment and growth using a model similar to that proposed by Nelson and Phelps (1966) and used by Benhabib and Spiegel (1994). After estimating the linear model we employ threshold regression models to examine whether the levels of human capital in a country affects the coefficient on investment in imported equipment. Our results indicate a large positive effect of investment in imported equipment on growth, consistent with existing results. Our results also suggest that the impact of imported equipment on growth is higher for countries beyond a certain threshold level of human capital, which supports our main hypothesis. Additional results also suggest that the return on imported equipment may be lower for countries with the highest levels of human capital, a result consistent with those of Temple and Voth (1998).

The remainder of the paper is structured as follows. In Section 2 we sketch a model similar to that proposed by Nelson and Phelps (1966) that relates equipment investment and human capital to output growth. Section 3 discusses our approach to empirically estimating the model and the data used in our analysis. In Section 4 we discuss the results from our model, while Section 5 reports the results of a number of robustness tests. Section 6 offers some conclusions.

2. Methodology

To consider the role of human capital in affecting the relationship between imported equipment and growth we adapt the approach of Benhabib and Spiegel (1994) who build upon the model of Nelson and Phelps (1966)[9]. Before describing the model we need to consider how human capital should be treated in our model. In general, there are two approaches to including human capital in growth regressions. One approach following Nelson and Phelps (1966) relates the growth of output to the *level* of human capital. Here human capital is assumed to affect growth through two channels, firstly by increasing a country's ability to undertake domestic innovation and secondly through its ability to facilitate technology adoption. This is the approach adopted by Benhabib and Spiegel (BS) (1994). The second approach, based on Lucas (1988) treats human capital like an ordinary input into a standard production function. As such the growth rate of output depends upon the *growth rate* of human capital.

For our purposes the Nelson and Phelps approach seems the most applicable, since this provides a role for human capital in the diffusion and adoption of technology. In what follows we sketch a simple growth accounting framework similar to BS that links capital goods investment, human capital and output growth. The starting point is a fairly standard constant returns to scale Cobb-Douglas production function,

[9] It would also be possible to develop a similar model linking investment in imported equipment and human capital to growth using the Solow model of Mankiw, Romer and Weil (1992). Temple (1998) for example develops a Solow model that distinguishes between capital equipment investment and investment in structures using such a model. As Temple (1998) notes however the common assumption of constant returns to scale in such a model may not be ideal, as one interpretation of existing results linking equipment investment to growth is that there are strong productivity externalities to equipment investment that may lead to increasing returns to scale at the aggregate level. Moreover, the results of Temple (1998) amongst others suggest that the returns to equipment investment are far too high to be consistent with the Neoclassical model's assumptions.

$$Y_{it} = A_{it} K_{it}^{O\,\alpha} K_{it}^{E\,\beta} L_{it}^{\;1-\alpha-\beta} \varepsilon_{it} \quad (1)$$

where Y_{it} is output in country i in period t, A is the level of technology (i.e. Total Factor Productivity), K^E is the stock of imported equipment, K^O is the stock of other capital, L is the labour force and ε an error term. The main difference between this and more standard production functions is the splitting of the imported equipment and the remaining capital stock[10].

Rewriting equation (1) allows us to consider a relationship between the level of GDP per worker and the inputs into the production function and can be expressed as,

$$y_{it} = A_{it} K_{it}^{O\,\alpha} K_{it}^{E\,\beta} L_{it}^{\;-\alpha-\beta} \varepsilon_{it} \quad (2)$$

where y_{it} is GDP per worker. Taking log differences of equation (2) gives us an expression for the growth rate of GDP per worker,

$$\Delta y_{it} = \Delta A_{it} + \alpha \Delta K_{it}^{O} + \beta \Delta K_{it}^{E} - (\alpha + \beta)\Delta L_{it} + \Delta \varepsilon_{it} \quad (3)$$

where Δ indicates a logarithmic growth rate.

What remains is for us to define a form for the growth of technology. In the spirit of Nelson and Phelps (1966) we specify the growth of technology as,

$$\Delta A_{it} = \gamma_1 + \gamma_2 H_{it} + \gamma_3 H_{it} \Delta K_{it}^{E}, \quad (4)$$

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[10] In the existing literature on equipment investment it is more common to distinguish between equipment investment and investment in structures. Given our decision to concentrate on imported equipment, we choose not to make this distinction. While the lack of ability and resources to produce equipment in most developing countries would suggest that domestically produced investment goods would largely exclude equipment goods, we may expect that in some countries there exists some capacity to produce equipment, hence the other capital stock may include some investment in domestically produced equipment. We also choose not to distinguish between domestic and foreign produced investment goods since some of what we term other capital will not be produced domestically, but be imports of non-equipment investment.

where H_{it} is the level of human capital in country *i* in period *t*. Here γ_1 represents exogenous technological progress. H_{it} is included to account for domestic innovation, while $H_{it}\Delta K_{it}^{E}$ represents technology diffusion from abroad, which is assisted by high levels of human capital in the recipient country. The difference between this specification and that of BS is that while BS assume that the extent of technological diffusion is dependent upon the gap in incomes between country *i* and the technology leader, we assume that the extent of technological diffusion depends upon the level of investment in imported equipment from the technological leaders. Our approach of considering investment in imported equipment rather than the stock of imported equipment reflects the hypothesis that a continuous stream of advanced technology embodied in capital goods is required to generate persistent externalities.

Combining equations (3) and (4) gives us the following estimating equation,

$$\Delta y = \gamma_1 + \gamma_2 H_{it} + \gamma_3 H_{it}\Delta K_{it}^{E} + \alpha\Delta K_{it}^{O} + \beta\Delta K_{it}^{E} - (\alpha+\beta)\Delta L_{it} + \Delta\varepsilon_{it} \qquad (5)$$

which relates the growth rate of GDP per worker to the growth in the stock of imported equipment, the growth in the stock of other capital, labour force growth, the level of human capital and the level of human capital interacted with the growth of the imported equipment stock, this last term capturing any inter-relationships between domestic human capital and imported equipment.

3. Empirical Method and Data

The starting point for our empirical analysis is equation (5). In our empirical analysis we modify this equation in a number of ways. Due to data limitations we are forced to define some of the variables differently to their description in Equation (5). Firstly, the lack of data on the labour force for many countries leads us to replace labour force growth with population growth and GDP per worker with GDP per capita. Rather than construct the capital stock using the perpetual inventory method we also follow the usual procedure in growth regressions and replace the growth of imported equipment capital stock and the growth of the other capital stock with the shares of investment in imported equipment and other capital in GDP respectively. The construction of these variables along with the definition of our human capital variables is described in the data section below. Finally, since we are considering a panel with up to eight time periods we add to equation (5) a full set of time dummies, which allow us to control for heterogeneity in performance across time, due to common shocks. This is equivalent to allowing the coefficient on the exogenous technological progress term to vary across periods.

The question of how to model the non-linear term remains open. The most straightforward method would be to include an interaction term between the level of human capital and investment in imported equipment. Including such an interaction term is our initial approach to modelling any inter-relationships between human capital and imported equipment. We would also like to have a richer set of possibilities for this non-linear term however, in particular allowing for any interaction between human capital and imported equipment to be non-monotonic. As such we also employ the panel threshold regression model of Hansen (1999). Threshold analysis allows the coefficient associated with imported equipment to vary discretely depending upon the value of a third variable, in our case human capital[11]. We can illustrate the threshold technique in the single threshold (i.e. two-regime) model, in which case we have,

$$\gamma_3 H_{it} \Delta K_{it}^{E} = \gamma_{3,1} \mathrm{I}_{(H_{it} \leq \lambda_1)} \Delta K_{it}^{E} + \gamma_{3,2} \mathrm{I}_{(H_{it} > \lambda_1)} \Delta K_{it}^{E},$$

where $\mathrm{I}_{(.)}$ is the indicator function and λ_1 is the estimated threshold. Here the observations are divided into two regimes depending upon whether the level of human capital is smaller or larger than the estimated threshold, λ_1. The impact of investment in imported equipment on growth will be given by $\gamma_{3,1}$ for observations in the low regime $(H_{it} \leq \lambda_1)$ and by $\gamma_{3,2}$ for observations in the high regime[12] $(H_{it} > \lambda_1)$. To estimate the model we firstly have to estimate the threshold, λ_1. The threshold parameter is estimated as the value that minimises the concentrated sum of squared errors from the least squares regression. Having found the threshold we need to identify whether it is statistically significant. To do this we need to test the null hypothesis that $\gamma_{3,1} = \gamma_{3,2}$. One complication in testing this is that the threshold, λ_1, is not identified under the null hypothesis, implying that classical tests do not have standard distributions. We follow Hansen (1999) and bootstrap to obtain the *p*-value for the test[13].

One advantage of Hansen's method is that it can be extended to consider the possibility of more than one threshold (i.e. more than two regimes), thus allowing for more flexibility in the non-linear relationship than simple interaction terms. While it is

[11] The validity of the threshold model relies on the threshold variable, human capital, being exogneous. To help deal with this potential problem we use data on our measures of human capital at the beginning of the period.
[12] To ensure a reasonable number of observations in each regime we impose the restriction that at least 10 percent of observations must lie in each regime.
[13] The bootstrap distribution of the test statistic was computed using 1000 replications of the procedure proposed in Hansen (1999).

straightforward to search for more than one threshold simultaneously, this can be expensive in terms of computation time. Bai and Perron (1998) amongst others have shown however that sequential estimation is consistent, thus avoiding this computation problem. In the two threshold case, the method involves fixing the first threshold at its estimated value, $\hat{\lambda}_1$, and searching for a second threshold assuming that the first threshold is fixed. This method can then be extended to any number of thresholds. To test for the significance of the second threshold the bootstrap procedure is once again followed, with the test discriminating between one and two thresholds[14].

3.1. Data

The model described in equation (5) is estimated on a sample of up to 55 developing countries[15] and up to eight five-year periods between 1960 and 1999, giving a possible 440 observations[16]. For the empirical analysis much of the data is taken from the Penn World Tables (version 6.1). This is the case for data on GDP per capita (from which growth rates and initial GDP per capita are calculated), the overall investment rate and the growth rate of openness, defined as the level of imports plus exports to GDP.

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[14] It can be shown in the two threshold model that the first threshold is asymptotically inefficient since it was estimated using a sum of squares function contaminated by the presence of a neglected regime. We follow Bai (1997) and re-estimate the first threshold holding the second one fixed. In no case however did the estimated threshold change.

[15] The 55 importing countries are Algeria, Argentina, Bangladesh, Bolivia, Botswana, Brazil, Cameroon, Central African Republic, Chile, Colombia, Democratic Republic of the Congo, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Israel, Jamaica, Kenya, Republic of Korea, Malawi, Malaysia, Mauritius, Mexico, Mozambique, Nepal, Nicaragua, Niger, Pakistan, Paraguay, Peru, Philippines, Poland, Senegal, Singapore, South Africa, Sri Lanka, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Zambia and Zimbabwe.

[16] Due to missing values on certain variables the maximum number of observations in our sample is 413.

Data on imports of equipment are taken from the OECD's International Trade by Commodity Statistic. This database reports the value of machinery and transport equipment from OECD countries to their individual trading partners. This measure is a good approximation of the total value of capital goods imported by each country from its higher income trading partners at (current) world prices (Lee, 1995). Investment in imported equipment was calculated by summing the imports of machinery and transport equipment to a particular country from each of 21 OECD countries[17].

To construct our measures of investment in imported equipment and other investment we adopt the following approach. Given that total investment includes that portion of investment that is imported we firstly subtract the value of imported equipment in a given year from the value of total investment in a given year to give us measures of investment in imported equipment and other capital. These two measures are then taken as ratios to GDP (in current international prices), which allows a ready comparison with existing studies.

The final variable we consider is a measure of human capital. Most studies examining the impact of education on growth use either flow measures such as enrolment ratios, or stock measures such as the average years of education. We proceed to use the average years of schooling in the population over 15 as opposed to enrolment ratios since Pritchett (2001) argues that enrolment ratios are a poor measure of the stock of human capital, and indeed may be negatively correlated with the human capital stock. We

[17] The 21 OECD countries from which our developing countries import capital goods are Australia, Austria, Belgium, Canada, Denmark, Germany, Finland, France, Ireland, Italy, Japan, Luxemburg, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, UK and the USA.

consider the log of both the average years of secondary (*SYR*) and higher (*HYR*) schooling in the population over 15, taken from the Barro and Lee (2001) dataset[18].

4. Results

4.1. Initial Results

Table 1 below reports our initial results, with the variable names in the table corresponding to those used in Section 3. The only differences in terminology are the use of *SYR* and *HYR* in place of *H* to indicate the average years of secondary and higher schooling in the population respectively. Also included in the table are interactions between the variable capturing imported equipment and the average years of secondary ($SYR \times \Delta K^E$) and higher ($HYR \times \Delta K^E$) schooling. Finally, the tables also include tests of the restrictions that the coefficients on imported equipment and other investment are the same ($\Delta K^O = \Delta K^E$), that the sum of the direct contribution of human capital and its indirect contribution through imported equipment is zero ($H + H \times \Delta K^E = 0$), and that the combined effect of imported equipment is equal to zero ($\Delta K^E + H \times \Delta K^E = 0$).

[18] We consider both secondary and higher education since there is some evidence of complementarities among different types of human capital, with higher education important for understanding and adapting new technologies, and secondary education important in their application (World Bank, 1998). As such we may expect differences in the results we obtain concerning secondary and higher education.

Table 1: Initial Results

Δy	1	2	3	4	5
ΔL	-0.50 (-2.45)**	-0.43 (-1.95)*	-0.58 (-2.79)***	-0.41 (-1.88)*	-0.61 (-2.93)***
ΔK^O	0.13 (6.31)***	0.13 (5.78)***	0.15 (7.03)***	0.13 (5.77)***	0.15 (7.04)***
ΔK^E	0.12 (3.03)***	0.11 (2.98)***	0.09 (2.96)***	0.06 (1.12)	0.26 (2.14)**
SYR		0.002 (1.05)		-0.001 (-0.26)	
HYR			-0.001 (-1.05)		-0.003 (-1.45)
$SYR \times \Delta K^E$				0.13 (1.96)*	
$HYR \times \Delta K^E$					0.07 (1.36)
$\Delta K^O = \Delta K^E$	0.11	0.12	2.78*		
$H + H \times \Delta K^E = 0$				4.01**	1.81
$\Delta K^E + H \times \Delta K^E = 0$				15.81***	3.67*
F-Statistic	10.08***	9.24***	10.74***	10.13***	10.48
R^2	0.23	0.23	0.23	0.23	0.23

Notes: All regressions include time dummies, which are not reported for brevity. The maximum number of observations available is 413. t-statistics are reported in brackets. All regressions estimated using White Heteroscedasticity-Consistent standard errors. *, ** and *** indicate significance at the 10, 5 and 1 percent level respectively.

Column 1 of Table 1 reports the results of estimating equation (3). Estimating equation (3) gives us, as expected, a significant negative coefficient on population growth and positive and significant coefficients on investment in both imported equipment and other capital[19]. Interestingly, the coefficients on the two investment variables are similar in size and we cannot reject the hypothesis that the two coefficients are equal at standard significance levels ($\Delta K^D = \Delta K^F$). The results suggest that a one percent increase in the ratio of investment to GDP (either imported equipment or other investment) would increase the growth of per capita GDP by around 0.13 percent per year. The size of the coefficient is slightly smaller than many of the coefficients reported by DS (1991), but is

[19] We are unable to reject the hypothesis of constant returns to scale using the results of Column 1 of Table 1 at conventional levels.

not out of line with many of those reported in the literature. While many of the results of DS suggest that the coefficient on investment in capital equipment is larger than that on other investment, De Long and Summers (1992) do find some evidence when using Lee's (1995) import data to suggest that the coefficient on equipment investment is the same as that on other investment. Similarly, Auerbach et al (1994) also find coefficients on equipment and non-equipment investment that are quite similar once outliers have been excluded from their analysis. As such our results are not without precedent.

We now turn to the role of human capital in the relationship between imported equipment and growth. Columns 2 and 3 of Table 1 include *SYR* and *HYR* in a linear fashion. These results are included to allow us to consider the direct impact of human capital on per capita GDP growth, usually considered to occur through human capital's impact on domestic innovation. The coefficients on the human capital variables are found to be positive for *SYR* and negative for *HYR*, though in neither case are they significant. Insignificant coefficients and even negative coefficients on measures of human capital have often been found in the empirical literature (see for example, Benhabib and Spiegel, 1994; Pritchett, 2001)[20]. In the spirit of Nelson and Phelps (1966) the level of human capital is included in our model to account for domestic innovation, which in developing countries tends to be limited. As a result we may not expect a positive and significant coefficient on human capital for developing countries. Such a result does not necessarily

[20] A number of explanations for such insignificant coefficients have been proposed. One explanation relates to the fact that many measures of human capital (including the ones used here) are not adjusted for differences in the quality of education (Krueger and Lindahl, 2001); while Temple (1999a) argues that the relationship between education and growth is hidden by unrepresentative observations. A further possibility relates to the notion that in developing countries a significant proportion of educated individuals are engaged in rent seeking and directly unproductive activity or in the public sector, which can inhibit growth by drawing educated people away from the most productive sectors (Pritchett, 2001).

imply a limited role for human capital. On the one hand, human capital can affect growth through its impact on other growth promoting variables, such as technology diffusion. On the other hand, Engelbrecht (2003) suggests that human capital may be better modelled as a standard factor in an aggregate production function implying that we should consider the relationship between the growth of output and the *growth* of human capital. This is something to which we return in Section 5.

The final two columns of Table 1 report the results from including the interactions between our two measures of human capital and investment in imported equipment. This specification corresponds to that given by equation (5). The coefficients on the interaction terms are both found to be positive, and in the case of secondary schooling the coefficient is found to be significant. As such, the results suggest that the benefits of imported equipment are higher in countries with higher levels of human capital, particularly secondary education.

4.2. Threshold Results

While the results described above are suggestive of the importance of human capital in enhancing the benefits of imported investment, we proceed to consider the possibility of threshold effects in the relationship between imported investment and growth, which allows us to consider the possibility of a richer set of non-linear interactions between human capital and investment in imported equipment. We begin by estimating a single threshold on imported investment, dependent upon the level of both *SYR* and *HYR*. The results are reported in Table 2.

Table 2: Initial Threshold Results

Δy	1	2
ΔL	-0.44 (-2.03)**	-0.63 (-3.05)***
ΔK^O	0.13 (6.12)***	0.15 (7.21)***
ΔK^E $(H_{it} \leq \lambda_1)$	-0.39 (-2.92)***	-0.14 (-1.52)
ΔK^E $(H_{it} > \lambda_1)$	0.13 (3.65)***	0.12 (4.92)***
SYR	-0.002 (-0.88)	
HYR		-0.003 (-1.99)**
λ_1	-1.48*** (18th percentile)	-3.02*** (46th percentile)
F-Statistic	10.91***	12.07***
R^2	0.24	0.24

Notes: All regressions include time dummies, which are not reported for brevity. t-statistics are reported in brackets. All regressions estimated using White Heteroscedasticity-Consistent standard errors. *, ** and *** indicate significance at the 10, 5 and 1 percent level respectively. The table reports the estimated values of the thresholds along with the percentile of the distribution at which the thresholds were found. The significance of the estimated threshold is found using 1000 replications of the bootstrap procedure of Hansen (1999).

Column 1 of Table 2 reports the results when the threshold variable is *SYR*. Here we find a threshold at a (logged) value of *SYR* of -1.48 (corresponding to an average of 0.23 years of secondary schooling). This threshold is found to be significant at the 1 percent level using the bootstrap procedure of Hansen (1999). The coefficients on investment in imported equipment in the two regimes indicate a significant negative coefficient in the low regime and a significant positive coefficient in the high regime. As such these results tend to support our main hypothesis that higher levels of human capital enhance the benefits of imported equipment.

Column 2 of Table 2 reports the results for a single threshold based on *HYR*, with the results being quite similar. Once again we find that the threshold, estimated to be at a (logged) value of -3.02 years of higher education (corresponding to 0.05 average years of higher schooling in the population over 15), is significant at the 1 percent level. The coefficients on imported equipment are once again found to be negative in the low regime, albeit insignificant, and positive and significant in the high regime.

4.3. Testing for Any Remaining Non-Linearity

As noted above one major advantage of the Hansen threshold model is that it allows us to consider the possibility of testing for more than one threshold. In this sub-section we test for any remaining non-linearities in our data, adopting the sequential approach described in Section 3. This involves fixing the first threshold at its estimated value and searching for a second threshold, which if significant leads us to consider a third threshold and so on[21]. Table 3 reports the results for the optimal number of thresholds, which are those for the last significant estimated threshold.

The results when *SYR* is our threshold variable (Column 1) indicate three significant thresholds (i.e. four regimes). Thresholds are found at logged values of *SYR* of -1.48 (0.23 average years of secondary schooling), 0.05 (1.05 years) and 0.42 (1.52 years), which correspond to the 18th, 68th and 84th percentiles of the distribution respectively. In the table ΔK^E (1) refers to the coefficient on imported equipment in the lowest regime (i.e. for log values of *SYR* less than or equal to -1.48), ΔK^E (2) to the coefficient on

[21] We maintain the restriction that at least 10 percent of observations must be in each regime.

imported equipment in the second lowest regime (i.e. for log values of *SYR* between -1.48 and 0.05) and so on. The results suggest a fairly complex interrelationship between human capital and imported equipment, and thus provide support for using threshold techniques over simple interaction terms. As for the single threshold results we find a significant negative coefficient on imported equipment in countries with the lowest levels of secondary schooling. This is followed by an insignificant coefficient in the second regime. In the final two regimes we find positive and significant coefficients on imported equipment, with the coefficient in Regime 3 being significantly greater than that in Regime 4. The coefficient in Regime 3 is particularly high and suggests large returns to investment in imported equipment, i.e. a 1 percent increase in imported equipment will increase growth by 0.53 percent. While this coefficient appears rather high it is not out of line with results reported by Temple and Voth (1998).

The second column of Table 3 reports the optimal threshold results when *HYR* is our threshold variable. In this case we find only two significant thresholds at the 12th and 46th percentiles, corresponding to logged values of *HYR* of -4.44 (0.01 years of higher schooling) and -3.02 (0.05 years). Despite finding fewer significant thresholds the results are to an extent similar to those using *SYR*. In particular we continue to find a significant negative coefficient in the low regime, followed by an insignificant coefficient in the second regime and a significant positive coefficient in the high regime[22].

[22] Although the estimated third threshold was insignificant the coefficients after allowing for a third threshold on *HYR* match those when using *SYR*. The results indicate a large positive and significant coefficient in Regime 3 and a smaller positive and insignificant coefficient in Regime 4. These results also provide some support therefore for the hypothesis of diminishing returns to imported equipmentl as human capital levels increase, though we are unable to reject the hypothesis that the coefficients in regimes 3 and 4 were the same in this case.

Table 3: Optimal Number of Thresholds

Δy	1	2
ΔL	-0.38 (-1.80)*	-0.63 (-3.09)***
ΔK^O	0.14 (6.39)***	0.15 (7.10)***
ΔK^E (1)	-0.48 (-3.20)***	-0.51 (-2.83)***
ΔK^E (2)	0.04 (0.49)	-0.12 (-1.36)
ΔK^E (3)	0.43 (2.83)***	0.12 (5.21)***
ΔK^E (4)	0.13 (5.20)***	
SYR	-0.003 (-1.66)*	
HYR		-0.005 (-2.52)**
λ_1	-1.48*** (18th percentile)	-4.44** (12th percentile)
λ_2	0.05** (68th percentile)	-3.02*** (46th percentile)
λ_3	0.42*** (84th percentile)	
F-Statistic	11.29***	11.95***
R^2	0.27	0.25

Notes: All regressions include time dummies, which are not reported for brevity. t-statistics are reported in brackets. All regressions estimated using White Heteroscedasticity-Consistent standard errors. *, ** and *** indicate significance at the 10, 5 and 1 percent level respectively. The table reports the estimated values of the thresholds along with the percentile of the distribution at which the thresholds were found. The significance of the estimated thresholds, λ_i (i=1,2,3), are found using 1000 replications of the bootstrap procedure of Hansen (1999). The estimated threshold values are listed in size order in the table, which is not necessarily the order in which the thresholds were estimated.

4.4. Discussion

The results described above indicate a positive impact of imported equipment investment on growth in developing countries when included linearly. The main result from our empirical analysis however, is that countries with higher average years of both secondary and higher schooling tend to benefit to a greater extent from investment in imported equipment than other countries. This supports our main hypothesis. Further interesting results are also found using threshold analysis however. We find evidence of a negative relationship between investment in imported equipment and growth for countries with the lowest levels of human capital. There is also some evidence that beyond a certain level of human capital the coefficient on imported equipment decreases, suggesting the possibility of diminishing returns to investment in imported equipment.

While differences in methodology, country samples and variable measurement make a comparison of our results with the existing literature difficult a number of similarities and differences arise. Our result that the relationship between investment in imported equipment and growth is stronger in countries beyond a certain threshold level of human capital is supportive of the results of Hendricks (2000) and Eaton and Kortum (2001). Our results may be considered less supportive of the results of Temple and Voth (1998) who suggest that the returns to investment in capital goods fall as human capital levels increase. One explanation for the difference in results between Temple and Voth (1998) and those reported here and by Hendricks (2000) and Eaton and Kortum (2001) is the use by Temple and Voth of enrolment ratios rather than average years of schooling. As mentioned above enrolment ratios being a flow measure are often a poor measure of the stock of human capital, which is the variable most relevant to our analysis[23].

[23] It should be noted however that for the purposes of Temple and Voth (1998) enrolment ratios may be the more relevant variable, since they relate the *accumulation* of human capital to industrialisation, which in turn impacts upon both growth and equipment investment. In their empirical analysis however they consider the relationship between equipment investment and growth for countries at different stages of industrialisation. It could be argued that the average years of education (a stock variable) would be a better measure of the stage of industrialisation than enrolment ratios (a flow variable).

An alternative interpretation of our results would be that it provides support for the results of both Hendricks (2000) and Eaton and Kortum (2001) *and* Temple and Voth (1998). The results presented here suggest that imported equipment only has a positive impact on growth for countries beyond a certain level of human capital, which is consistent with Hendricks (2000), and Eaton and Kortum (2001). Our results also suggest a diminishing impact of imported equipment for countries with the highest levels of human capital however, a result consistent with those of Temple and Voth (1998), at least for that portion of our data.

Temple and Voth (1998) suggest that the reason for diminishing returns to equipment investment is that countries with low levels of human capital have more potential for industrialisation, which when it takes place is associated with high productivity growth and increased equipment investment. As such the strong relationship between equipment investment and growth they find for countries with relatively low levels of human capital is being driven by the effect of industrialisation. For countries with high levels of human capital that have already industrialised Temple and Voth expect to find little relationship between equipment investment and growth. This conclusion is consistent with our results suggesting diminishing returns to imported equipment for the portion of our data with the highest levels of human capital. Such a relationship for countries with the lowest levels of human capital is unlikely to hold if they are not yet in a position to industrialise, due for example to a lack of resources or small market size.

The explanation of Temple and Voth (1998) cannot be considered a full explanation for our results however, since we still find a significant effect of imported equipment on growth even for the countries with the highest levels of human capital and because the returns to imported equipment initially rise as human capital increases. An alternative explanation argues that as countries' levels of human capital increase towards levels similar to those found in advanced countries they are able to produce their own capital goods. In such countries imports of equipment thus provides competition for domestic capital goods sectors, which may lower output in these sectors. A further argument relates to the role of imported equipment in encouraging technology diffusion. The major benefit of imported equipment for countries with average levels of human capital may arise due to reverse engineering and imitation. Countries with relatively high levels of human capital may have moved beyond the imitation stage, themselves engaging in innovation[24]. While technology diffusion through imported equipment may still be beneficial for these countries by encouraging incremental innovation, the benefits may be lower than for countries relying solely on imitation. This explanation would also explain why we still find a significant coefficient for countries with high levels of human capital.

The negative relationship between imported equipment and growth for countries with the lowest levels of human capital is more difficult to explain. One explanation argues that increasing technology imports in isolation to increases in human capital is unlikely to lead to enduring growth and may have negative developmental effects from rising inequality. An alternative view is that investment in relatively high-tech imported

[24] Countries classified in the high regime according to the level of *SYR* include Israel, Philippines, South Korea, Malaysia and Singapore. These are countries that at least towards the end of our sample have developed some capacity for innovative activities.

equipment will be of little benefit, and may have negative effects, in countries that are lacking the skills to understand and operate such equipment or to benefit from knowledge diffusion and reverse engineering. In such cases investing in imported equipment will be unlikely to increase the productive capacity of the economy, whilst reducing investment in more relevant and productive domestic capital.

5. Robustness

In this section we examine the robustness of the results found in the previous section. In particular, we examine the robustness of our results when allowing for interactions between human capital and other investment, to alternative definitions of imported equipment, to the inclusion of additional variables and by accounting for the possibility of the investment rates being endogenous[25].

5.1. Robustness to Thresholds on Other Investment

While the focus of this paper is on potential interactions between imported equipment and human capital, it is important to examine whether any results we get on this are being driven by thresholds on other investment and human capital. As such we examine whether there are interactions between other investment and human capital. Initially, this is achieved by considering interactions between other investment and human capital. The results are reported in Table 4. Interestingly, the coefficients on the interaction between other investment and human capital are negative, and in the case of higher schooling significant. This suggests that if anything higher levels of human capital actually lower

[25] We can also consider the use of data on both secondary and higher schooling as an alternative test of robustness.

the impact of other investment on growth. The impact of imported equipment remains positive and significant, often increasing in size, and the interaction between this variable and human capital is also found to be positive and significant, even in this case for years of higher schooling.

Table 4: Interactions with other investment

Δy	1	2	3	4
ΔL	-0.45 (-2.05)**	-0.44 (-2.01)**	-0.61 (-2.93)***	-0.67 (-3.26)***
ΔK^O	0.12 (4.85)***	0.11 (4.57)***	0.07 (1.51)	0.04 (0.81)
ΔK^E	0.12 (3.04)***	0.06 (1.16)	0.09 (3.10)***	0.37 (3.17)***
SYR	0.003 (1.06)	0.0001 (0.22)		
HYR			0.002 (0.62)	-0.0002 (-0.09)
$SYR \times \Delta K^O$	-0.01 (-0.61)	-0.016 (-0.91)		
$HYR \times \Delta K^O$			-0.03 (-1.81)*	-0.04 (-2.43)**
$SYR \times \Delta K^E$		0.14 (2.11)**		
$HYR \times \Delta K^E$				0.11 (2.32)**
F-Statistic	24.32***	24.07***	25.70***	25.30***
R^2	0.38	0.39	0.38	0.39

Notes: All regressions include time dummies, which are not reported for brevity. The maximum number of observations available is 413. t-statistics are reported in brackets. All regressions estimated using White Heteroscedasticity-Consistent standard errors. *, ** and *** indicate significance at the 10, 5 and 1 percent level respectively.

We move on to examine interactions between other investment and human capital using threshold analysis. The results are presented in Table 5. We begin in the first two columns by including equipment investment linearly and searching for the optimal number of thresholds on other investment. In the case of SYR we find one significant threshold, while for HYR we find two. The results however are largely consistent and suggest that the benefits of other investment for growth diminish as the level of human capital increases. The coefficient on imported equipment remains positive and significant.

Table 5: Optimal Number of Thresholds

Δy	1	2	3	4
ΔL	-0.52 (-2.38)**	-0.68 (-3.36)**	-0.50 (-2.42)**	-0.73 (-3.65)***
ΔK^O (1)	0.14 (6.33)***	0.23 (6.00)***	0.15 (6.96)***	0.23 (5.97)***
ΔK^O (2)	0.09 (3.11)***	0.15 (6.62)***	0.07 (2.31)**	0.15 (6.77)***
ΔK^O (3)		0.08 (2.52)**		0.08 (2.51)**
ΔK^E (1)	0.13 (3.35)***	0.09 (3.34)***	-0.49 (-3.31)***	-0.14 (-1.67)*
ΔK^E (2)			-0.11 (-1.36)	0.12 (5.51)***
ΔK^E (3)			0.18 (4.28)***	
SYR	0.004 (1.72)*		0.0006 (0.22)	
HYR		0.003 (1.36)		0.0008 (0.35)
λ_1^O	-0.09** (62nd Percentile)	-3.95*** (23rd percentile)	-0.09** (62nd Percentile)	-3.95*** (23rd percentile)
λ_2^O		-2.04** (71st Percentile)		-2.04** (71st Percentile)
λ_1^E			-1.48** (18th Percentile)	-3.02*** (46th Percentile)
λ_2^E			0.05*** (68th Percentile)	
F-Statistic	24.49***	24.37	24.37	27.12***
R^2	0.39	0.40	0.41	0.41

Notes: All regressions include time dummies, which are not reported for brevity. t-statistics are reported in brackets. All regressions estimated using White Heteroscedasticity-Consistent standard errors. *, ** and *** indicate significance at the 10, 5 and 1 percent level respectively. The table reports the estimated values of the thresholds along with the percentile of the distribution at which the thresholds were found. The significance of the estimated thresholds, λ_i (i=1,2,3), are found using 1000 replications of the bootstrap procedure of Hansen (1999). The estimated threshold values are listed in size order in the table, which is not necessarily the order in which the thresholds were estimated.

In the final two columns we impose the optimal number of thresholds on other investment reported in Columns 1 and 2 and then search for the optimal number of thresholds on imported equipment[26]. For SYR we find evidence of two thresholds on imported equipment. In the low regime we again find a significant negative coefficient on imported equipment, which is followed by an insignificant negative coefficient and a positive and significant coefficient in the high regime. This is largely consistent with results reported above, though we find no evidence of diminishing returns to imported equipment. For HYR we find only a single threshold, with the coefficients being negative in the low regime and positive in the high regime. Such a result is consistent with those reported above, with only countries with relatively high levels of human capital benefiting from imported equipment.

5.2. Robustness to Alternative Definitions of Imported Equipment

To date we have used imports of machinery and transport equipment from 21 OECD countries as our measure of imported equipment. In this sub-section we consider alternatives to this measure. Our first alternative is to consider imports of machinery equipment only. Excluding transport equipment from our measure of imported equipment investment may be considered a more accurate measure of imports of equipment investment, since transport equipment could be better considered infrastructure investment. Our second alternative is to concentrate on imports from the G5 (France, Germany, Japan, UK, USA) countries only. The reason for such a choice relates to the fact that even within the OECD R&D activities are heavily concentrated. Eaton and Kortum (1999) note that in the late 1980s 80 percent of OECD research scientists and

[26] Since the estimates of the thresholds on other investment may be affected by the presence of a threshold on imported equipment, we re-estimate the thresholds on other investment fixing the thresholds on imported equipment (see Bai (1997) for more on this issue). In no case however, did the estimated thresholds change.

engineers were employed in the G5 economies. As such we may expect the major benefits of imported equipment to come through trade with these five countries. Finally we combine these two arguments to consider imports of machinery equipment only from the G5 countries. The results are reported in Tables 6, with the first three columns reporting the results from using machinery imports only, the second three columns from using imports of machinery and transport equipment from the G5 only and the final three columns from using imports of machinery from the G5 countries only.

The results when using machinery imports only and when using imports of machinery and transport from the G5 are qualitatively similar from those results reported above. When using imports of machinery only from the G5 only we again find similar results, though no evidence of diminishing returns to investment in imported equipment is found for either the average years of secondary or higher schooling.

Table 6: Results using Machinery Imports only

Δy	Machinery Imports			Machinery and Transport Imports from the G5			Machinery Imports from the G5		
	1	2	3	4	5	6	7	8	9
ΔL	-0.50	-0.40	-0.65	-0.50	-0.41	-0.61	-0.50	-0.45	-0.62
	(-2.46)**	(-1.90)*	(-3.16)***	(-2.44)**	(-1.93)*	(-2.98)***	(-2.44)**	(-2.06)**	(-3.04)***
ΔK^O	0.13	0.14	0.15	0.13	0.14	0.15	0.13	0.13	0.15
	(6.41)***	(6.39)***	(7.18)***	(5.93)***	(6.18)***	(6.69)***	(6.02)***	(5.97)***	(6.78)***
ΔK^E (1)	0.12	-0.72	-0.83	0.14	-0.73	-0.66	0.14	-1.16	-1.16
	(2.51)**	(-2.71)***	(-3.03)***	(3.08)***	(-3.88)***	(-2.61)***	(2.67)***	(-4.24)***	(-2.89)***
ΔK^E (2)		-0.01	-0.21		0.09	-0.14		0.15	-0.27
		(-0.07)	(-1.72)*		(0.75)	(-1.13)		(3.07)***	(-1.44)
ΔK^E (3)		0.60	0.12		0.61	0.12			0.12
		(2.82)***	(3.96)***		(3.12)***	(4.88)***			(3.59)***
ΔK^E (4)		0.12			0.13				
		(3.82)***			(5.18)***				
SYR		-0.003			-0.004			-0.002	-0.004
		(-1.29)			(-1.76)*			(-0.92)	(-2.23)**
HYR			-0.005			-0.004			
			(-2.44)**			(-2.28)**			
λ_1		-1.48***	-4.5**		-1.48***	-4.44**		-1.48***	-4.45**
		(18th)	(12th)		(18th)	(12th)		(18th)	(12th)
λ_2		0.2***	-3.02***		0.18***	-3.03			-3.02**
		(73rd)	(45th)		(73rd)	(45th)			(45th)
λ_3		0.42***			0.42*				
		(84th)			(84th)				
$\Delta K^O = \Delta K^E$	0.08			0.01			0.02		
F-Statistic	10.03***	10.65***	12.14***	10.01***	12.34***	11.90	10.01***	10.83***	12.17***
R^2	0.23	0.26	0.25	0.23	0.27	0.24	0.23	0.25	0.24

Notes: As in Table 3. The measure of investment in imported equipment in the first three columns is imports of machinery only, in the second three columns it is imports of machinery and transport equipment from the G5 countries only, and in the final three columns it is imports of machinery from the G5 countries only.

5.3. Robustness to the Inclusion of Additional Variables

Our second robustness test is to include additional variables in our growth model. A number of additional variables are considered. Firstly, we adapt the way that we treat human capital in our model. As discussed in Section 2, there are in general two approaches to including human capital in growth regressions. To date we have followed Nelson and Phelps (1966) allowing the level of human capital to affect the growth rate of output. In this sub-section we also follow the Lucas approach and allow the growth rate of human capital to affect the growth rate of output, by considering human capital as an input in to a standard production function. Support for such a hybrid model allowing a role for both the growth and level of human capital in growth has been found by Engelbrecht (2003)[27].

Secondly, we consider the addition of two other variables that may well impact upon the relationships examined in this paper. The first of these is a measure of openness (ΔT), defined as the growth rate of imports plus exports to GDP, which is included to capture the impact on growth of other effects related to openness. Given the often considered positive relationship between openness and growth, we may expect that excluding this variable could bias upwards the coefficient on imported equipment, which itself captures to an extent the role of openness. The second variable we consider is initial GDP per capita (y_0), which is often included in growth regressions to account for the possibility of catch-up or convergence. An alternative view is that it captures initial efficiency, accounting for the fact that relatively poor economies tend to have lower stocks of

[27] Including the growth of human capital in our model, defined as the change in the log of human capital, means that we lose the first observation for each of our countries leaving us with a maximum of 355 observations.

capital, so that the marginal product of an additional unit of capital is higher in these countries, and their rate of growth will be higher for any given rate of investment. Excluding this variable could also bias our results on investment in imported equipment therefore. In addition to these two variables, a large number of other variables have been proposed in the empirical growth literature (see for example Sala-i-Martin, 1997; Doppelhofer et al, 2004). Rather than include a long list of other variables, we choose as our third set of additional variables a full set of country dummies, which are included to account for cross-country heterogeneity in growth performance.

The results from including these additional variables are reported in Table 7. The first four columns of Table 7 report the results from the hybrid model. The first two columns add the growth of *SYR* and *HYR* respectively to equation (3). The inclusion of these variables has little effect on the coefficients on the other variables in the model. The coefficients on the growth of human capital are themselves positive and in the case of *SYR* significant, providing some support for the Lucas approach to modelling the relationship between human capital and growth, as well as the conclusions of Engelbrecht (2003). The second two columns of Table 7 report the optimal threshold results using the hybrid model. In Column 3 we find a single threshold based on *SYR*, while in Column 4 we find two thresholds based on *HYR*. The results suggest a significant negative coefficient in the low regime, followed for *HYR* by an insignificant coefficient in the middle regime, followed by a significantly positive coefficient in the high regime for both *SYR* and *HYR*. These results therefore supports earlier results suggesting a negative impact of imported equipment in countries with the lowest levels of human capital, but a positive effect in countries with the highest levels.

Columns 5 through 7 report the results when including initial GDP per capita and the growth of openness. The linear results reported in Column 5 suggest that the impact of these variables has little impact on the other coefficients, with the coefficients on the two variables themselves being insignificant (and in the case of ΔT not of the expected sign[28]). The threshold results for *SYR* (Column 6) and *HYR* (Column 7) are consistent and suggest two significant thresholds. In the low regime we again find a significant negative coefficient, followed by an insignificant coefficient in the middle regime and a positive and significant coefficient in the high regime, results once again consistent with those reported earlier.

The final three Columns of Table 7 report the results when including a full set of country dummies in our analysis. Interestingly, in the linear model (Column 8) we find an insignificant coefficient on imported equipment. Despite this however, we are unable to reject the hypothesis that the coefficient on imported equipment is the same as that on domestic capital. The final two columns report the threshold results. In Column 9 we find two significant thresholds. The results suggest an insignificant impact of imported equipment in the low regime, followed by a positive and significant coefficient in the middle regime and an insignificant positive impact in the high regime. In this case therefore, the results support our earlier results of a positive impact of imported equipment above a certain threshold, and the result that the benefits of imported

[28] The result that the level of openness is not significant when a measure of the composition of trade is included is consistent with the results of Lee (1995) discussed in Section 1.

equipment diminish for countries with the highest levels of human capital. Column 10 reports the results for thresholds based on *HYR*, for which we find no evidence of a significant threshold. The results reported therefore are for the linear model that includes *HYR* as a dependent variable. While the results suggest no role for higher schooling in the relationship between imported equipment and growth, the coefficient on imported equipment is found to triple in size once *HYR* is included in the model.

The results using country fixed effects tend to be less consistent with earlier results. It is not uncommon however for fixed effects panel models to give disappointing results. Identification of the parameters with country specific fixed effects relies on variation over time within each country, such that the variation across countries is not used. As is noted by Durlauf et al (2004) the inclusion of fixed effects while reducing the bias associated with cross-country heterogeneity often results in higher standard errors and imprecise estimates. This leads Temple (1999b) to suggest that using carefully selected regional dummies may be preferred to individual country dummies, since much of the variation in efficiency levels occurs between rather than within continents. We adopt this approach including dummies for Sub-Saharan Africa, Latin America and East Asia. The results reported in Table 8 indicate that when including these dummies the coefficients on investment in imported equipment and other investment are positive and significant. The threshold results are also qualitatively similar to those reported in Tables 2 and 3 supporting our three major results, namely a negative relationship between imported equipment and growth for countries with the lowest levels of human capital, a positive relationship beyond a certain threshold level of human capital, and a smaller positive coefficient for countries with the highest levels of human capital.

Table 7: Results when Including Additional Variables

Δy	*Hybrid Model*				*Additional Variables*			*Country Dummies*		
	1	2	3	4	5	6	7	8	9	10
ΔL	-0.63	-0.55	-0.53	-0.70	-0.59	-0.48	-0.63	-0.18	-0.25	-0.21
	(-2.84)***	(-2.51)**	(-2.09)**	(-3.14)***	(-2.80)***	(-2.34)**	(-3.12)***	(-0.43)	(-0.57)	(-0.48)
ΔK^O	0.14	0.14	0.13	0.15	0.14	0.15	0.16	0.12	0.13	0.15
	(6.17)***	(5.94)***	(5.96)***	(6.83)***	(6.90)***	(7.18)***	(4.85)***	(3.54)***	(4.36)***	(5.25)***
ΔK^E (1)	0.09	0.08	-0.41	-0.47	0.13	-0.60	-0.54	0.08	-0.06	0.24
	(2.72)***	(2.73)***	(-2.78)***	(-2.39)**	(3.24)***	(-3.90)***	(-2.95)***	(0.49)	(-0.32)	(2.64)***
ΔK^E (2)			0.10	-0.14		-0.01	-0.11		0.48	
			(3.28)***	(-1.47)		(-0.13)	(-1.28)		(2.98)***	
ΔK^E (3)				0.15		0.18	0.13		0.10	
				(6.83)***		(4.23)***	(4.85)***		(0.80)	
SYR			-0.001			-0.001			-0.008	
			(-0.20)			(-0.51)			(-2.56)**	
HYR				-0.005			-0.005			-0.004
				(-2.31)**			(-2.30)**			(-1.37)
ΔSYR	0.01		0.01							
	(2.47)**		(2.66)***							
ΔHYR		0.001		0.002						
		(1.30)		(1.55)						
ΔT					-0.0001	-0.01	0.03			
					(-0.01)	(-0.28)	(0.81)			
y_0					-0.003	-0.007	-0.002			
					(-1.18)	(-2.25)**	(-0.69)			
λ_1			-1.48***	-4.39*		-1.48	-4.5		-1.48	
			(14th)	(12th)		(18th)	(12th)		(18th)	
λ_2				-3.02***		0.05	-3.03		0.4	
				(43rd)		(68th)	(45th)		(83rd)	
λ_3										
$\Delta K^O = \Delta K^E$	1.76	2.02	N/A	N/A	0.07	N/A	N/A	0.05	N/A	0.98
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummies	No	No	No	No	No	No	No	Yes	Yes	Yes
Observations	355	355	355	355	413	413	402	413	413	402
F-Statistic	9.69***	9.93***	9.53***	11.16***	9.34***	11.97***	11.97***	15.99	19.40***	15.84***
R^2	0.24	0.23	0.26	0.26	0.23	0.25	0.25	0.55	0.58	0.57

Notes: As for Table 3.

Table 8: Results Including Regional Dummies

Δy	1	2	3
ΔL	-0.40 (-1.85)*	-0.38 (-1.78)*	-0.44 (-2.03)**
ΔK^O	0.10 (4.32)***	0.11 (3.57)***	0.13 (5.78)***
ΔK^E (1)	0.09 (2.49)**	-0.40 (-2.57)***	-0.40 (-2.11)**
ΔK^E (2)		0.08 (0.90)	-0.06 (-0.61)
ΔK^E (3)		0.47 (3.42)***	0.23 (3.19)***
ΔK^E (4)		0.09 (3.57)***	0.07 (2.63)***
SYR		-0.003 (-1.56)	
HYR			-0.005 (-2.13)**
DLAT	-0.01 (-2.86)***	-0.01 (-2.66)***	-0.006 (-1.36)
DSSA	-0.01 (-2.90)***	-0.01 (-2.08)**	-0.014 (-2.98)***
DEAS	0.008 (1.65)*	0.007 (1.46)	0.006 (1.35)
λ_1		-1.48*** (18^{th})	-4.43** (12^{th})
λ_2		0.18** (73^{rd})	-3.03* (45^{th})
λ_3		0.42* (84^{th})	-2.65** (55^{th})
$\Delta K^O = \Delta K^E$	0.08		
F-Statistic	9.31***	10.79***	10.22***
R^2	0.26	0.29	0.28

Notes: As for Table 3. *DLAT*, *DSSA* and *DEAS* are regional dummy variables for Latin America, Sub-Saharan Africa and East Asia respectively.

5.4. Robustness and Endogeneity

Endogeneity is a key concern in the context of growth regressions. Endogeneity can arise for a number of reasons. For instance, it may be that two variables are correlated, but jointly determined by a third variable. This sort of endogeneity underlies the model of Temple and Voth (1998), whereby the correlation between equipment investment and growth is due to the process of industrialisation and structural change. Alternatively, a number of variables included in growth regressions are themselves decision variables and are thus likely to be endogenous. Investment is one such variable, with the finding of a relationship between investment and growth not indicating whether such a relationship is causal.

The most common response to the issue of endogeneity in growth regressions has been to employ instrumental variables estimation[29]. De Long and Summers (1991) employ instruments for their equipment investment variable[30]. In particular, they consider equipment prices, rates of national saving and measures of trade liberalization as instruments. The results when using these instruments are largely supportive of a causal relation between equipment investment and growth. Despite these results De Long and Summers (1991) acknowledge that there are good arguments for considering these instruments themselves endogenous (see also Temple, 1998) [31]. Given the difficulty in finding a reasonable set of instruments Temple (1998) proposes using lags of the equipment investment as instruments and continues to find high returns to equipment investment.

[29] An alternative approach to dealing with endogeneity is to model the endogenous variables using a simultaneous equation model (Tavares and Wacziarg, 2001).

[30] Lee (1995) also uses instrumental variables estimation for his measure of imported equipment, using land size, distance from trading partners and tariff rates as instruments.

[31] The major difficulty in finding a set of valid instruments involves finding instruments that are uncorrelated with the error term in the growth regression. If this is not the case instrumental variables estimates will be inconsistent and OLS may be preferred (Durlauf et al, 2005).

In terms of our empirical model both investment in domestically produced and imported equipment are likely to be endogenous variables[32]. To account for this endogeneity we follow the approach of Temple (1998) and use lags of investment in imported and domestically produced capital goods as instruments[33] (i.e. we use investment rates for 1960-64 for estimating the impact of investment on growth for 1965-69 and so on)[34]. The results from using the lagged investment as instruments are presented in Table 9.

Column 1 of Table 9 reports the linear results[35]. Here we find a positive coefficient on imported equipment, which is not significant. Despite this we cannot reject the hypothesis that the coefficient on imported equipment equals that on domestic capital. While the coefficient on domestic equipment is found to fall slightly it remains significant. The final two columns report the threshold results for both *SYR* and *HYR*, both of which support existing results. For *SYR* (Column 2) we find two significant thresholds. In the low regime we again find a significant negative coefficient on imported equipment, followed by an insignificant coefficient, with a positive and significant coefficient in the high regime.

[32] The possibility of human capital being endogenous is considered less often. Given however that the human capital data we have is measured at the beginning of each five-year period we can assume that these variables are pre-determined and consider that we are instrumenting for human capital in our model.
[33] Using lags as instruments means that we lose the first observation for each country leaving us with a maximum of 355 observations.
[34] Given that we are considering imports of capital goods an alternative instrument would be to follow Frankel and Romer (1999) and use geographical characteristics as instruments for imports of capital goods. Such an approach would not necessarily give us a more valid set of instruments however (see Brock and Durlauf, 2001; Durlauf et al, 2005). Moreover, adopting a two-stage least squares approach would not allow us to employ the threshold techniques that we have employed to examine the inter-relationships between human capital and imported equipment.
[35] The correlation between the lagged and actual values are found to be 0.92 for investment in imported equipment and 0.88 for investment in other capital. The correlation between the lagged variables and the residuals from the growth regression are both essentially zero.

For *HYR* (Column 3) we find three significant thresholds, with insignificant coefficients found in the bottom two regimes, followed by a significantly positive coefficient, and a significant negative coefficient in the high regime. The results on *HYR* suggest again therefore that imported equipment has a significant impact on growth in countries with a certain level of human capital. The results also suggest that the impact of imported equipment can diminish for countries with the highest levels of human capital, with a negative impact found in this case. While evidence of a diminishing impact of imported equipment for countries with the highest levels of human capital was found above, we found no evidence of a significant negative impact of imported equipment in these cases.

Table 9: Results when Using Instruments of the Investment Rates

Δy	1	2	3
ΔL	-0.62 (-2.70)***	-0.38 (-1.49)	-0.71 (-2.95)
ΔK^O	0.11 (4.60)***	0.09 (4.03)***	0.12 (4.85)***
ΔK^E (1)	0.04 (0.81)	-0.51 (-1.93)*	0.12 (0.56)
ΔK^E (2)		-0.12 (-1.34)	-0.17 (-1.56)
ΔK^E (3)		0.07 (1.87)*	0.08 (2.06)**
ΔK^E (4)			-0.29 (-2.26)**
SYR		0.002 (0.78)	
HYR			0.002 (0.69)
λ_1		-1.48* (14th)	-3.95* (21st)
λ_2		0.56* (90th)	-3.02** (43rd)
λ_3			-1.82* (77th)
$\Delta K^O = \Delta K^E$	1.45		
F-Statistic	7.74***	7.97***	6.80***
R^2	0.18	0.20	0.21

Notes: As for Table 3.

6. Conclusions

A literature emerged in the early 1990s suggesting a large positive and causal association between equipment investment and growth. Following these initial findings later studies considered and found a similar relationship between imported equipment in developing countries. In this paper we examine, using a panel of 55 developing countries over the period 1960-1999, the relationship between growth and imports of equipment from advanced countries that undertake the majority of R&D and produce the majority of capital goods. We also examine using threshold regression analysis the impact of human capital on the relationship between imports of equipment and growth.

Our results indicate that the returns to imported equipment are high, and are thus supportive of the results of DS. As such our results support the conclusions of DS, suggesting that policies that shift incentives toward making equipment investment cheaper and easier are likely to yield large benefits. Our focus on *imported* equipment suggests that trade policies could play an important role in providing firms with access to equipment in developing countries. At the same time however we find the coefficient on investment in imported equipment to be insignificantly different to that on other investment, tempering the conclusions of DS somewhat and suggesting that policies to raise investment in general are as likely to encourage growth as those specifically aimed at imported equipment.

Our main hypothesis that human capital helps countries gain the benefits of imported equipment is robustly supported by our results. We find that countries beyond a certain level of human capital benefit from imported equipment to a greater extent than countries below this level. This result appears to hold using data on both secondary and higher schooling. Investment in human capital is therefore likely to be an important policy. Investment in human capital can impact upon growth firstly through its role as a standard factor of production and secondly by maximising the benefits of investment in equipment.

Our threshold results also present other interesting results, which are supported to a greater or lesser extent by the data and our robustness tests. In particular, we find evidence to suggest that the benefits of human capital for the relationship between capital goods imports and growth tends to diminish for countries with the highest levels of human capital. While tending to remain positive and significant, the coefficient on imported equipment is often found to fall for countries with the highest levels of human capital. One possible explanation for this result is that the role of imported equipment in encouraging technology diffusion becomes less important in countries with large stocks of human capital and in countries that undertake significant innovative activity. This result is also consistent with the results of Temple and Voth (1998) who argue that there shouldn't be a strong relationship between equipment investment and growth for countries with high levels of human capital, since such countries would have already industrialised, which lowers the benefits of equipment investment.

A third result that often appears is a negative relationship between capital goods imports and growth for countries with the lowest levels of human capital. While we may expect to find little impact of imported equipment on growth in countries with low levels human capital and with little capacity to absorb and effectively employ imported equipment, a negative relationship is more difficult to explain. One explanation suggested in the literature is that higher levels of investment in capital goods may lead to higher levels of inequality, which can have negative effects on growth. Alternatively, it may be that investing in imported equipment is unproductive in countries without the resources to take advantage of the advanced technology it embodies, while also reducing investment in more effective and relevant domestic technology. This suggests that policies that promote equipment investment while neglecting investment in human capital are likely to result in limited gains in terms of growth and may have detrimental effects. Such a conclusion is largely consistent with the model of Hendricks (2000) who considers complementarities between human capital and equipment investment.

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