Imported Machinery and Growth in LDCs

Joy Mazumdar
Department of Economics
Emory University
December 1999
jmazumd@emory.edu

Abstract

While there seems to be some evidence in favor of the hypothesis that a more open trade regime leads to growth in developing countries, the mechanism by which trade leads to growth is far from obvious. One possible mechanism is that since developing countries have a comparative disadvantage in equipment production, a more open trade regime makes it possible to import machinery that is cheaper (or of superior quality). This paper finds evidence to support the claim that imported machinery leads to higher growth in developing countries. Using panel data with country fixed effects we find that investment in domestically produced equipment reduces the growth rate while investment in imported equipment increases it. We find no such effect for a sample of high income nations. This is consistent with our assumption that high income countries have a comparative advantage in equipment production. The advantage of this study over the Lee (1995) paper is that since we make a distinction between imported and domestically produced equipment we are able to distinguish our hypothesis from the DeLong and Summers hypothesis that equipment investment in general contributes more to growth.
1. INTRODUCTION

The rapid growth of the NICs (newly industrialized countries) in the past three decades has prompted other LDCs to liberalize their trade policies in favor of more open trade regimes since the NICs are thought to have achieved their high growth rates at least partly by adopting a more export oriented regime. There is also some evidence for the hypothesis that a more open trade regime leads to growth (see, for example, Dollar 1992 and Edwards 1992). The question that still needs to be answered is what is the mechanism by which trade leads to growth.

One possible mechanism is the import of machinery that a more outward oriented trade regime allows. It is well known that LDCs have a comparative disadvantage in machinery production. In 1980, imports of machinery and transport equipment into developing countries as a whole from developed nations constituted 43% of total developing country imports from developed countries. Whereas, exports from LDCs of machinery and transport equipment to developed areas constituted only 4% of total exports to developed countries. Around 85% of the imports of machinery and transport equipment into LDCs came from developed countries.

It is possible then that more open economies grow faster because they are able to invest in imported machinery that is cheaper (or of better quality). It might seem, at rst, that a way to test the hypothesis would be to see whether investment in imported machinery yields a higher return than investment in domestic equipment. This is the motivation behind a couple of studies in this area (Blomstrom, Lipsey, Zejan 1992 and Romer 1993). They consider cross country growth regressions with a set of explanatory variables that include both the overall investment rate and equipment imports as a fraction of gdp. Equipment imports are already included in the investment rate. If investment in imported equipment has a higher marginal product
than other forms of equipment then the coefficient of the imported equipment variable should be positive. Neither of these studies find any evidence that equipment imports have an additional effect on growth over and above the effect of total investment.

A little more reflection shows that one might not observe any connection between the fraction of investment in imported machinery and growth because of the following reason. In the presence of trade barriers the domestic price of the imported equipment will increase till the rates of return on the domestically produced and the imported equipment are the same. However, as we will show in the theory section, in spite of the equal rates of return from the two kinds of equipment, investment in imported equipment will lead to a higher growth rate than investment in the domestically produced variety. The reason for this is that the true opportunity cost of imported equipment is lower than that of domestic equipment, although the domestic prices are the same. The opportunity cost of imported equipment is equal to the international price which is lower than the domestic price. Therefore, a dollar spent on imported equipment does in fact buy more than if the dollar were spent on domestic equipment. The difference between the international price and the domestic price of imported machinery accrues as import-quota rent (or tariff revenue) which is available for investment. This quota rent is not available if the investment funds are spent on domestic equipment.

One paper that finds evidence for the hypothesis that imported machinery matters

---

\[1\] This effect, which involves the composition of investment, should be distinguished from the effect of a more open trade regime on the total investment rate. The availability of foreign machinery may decrease the domestic price of machinery which in turn will increase the real investment rate (i.e., the amount of capital goods a given investment rate buys) and may even increase the investment rate itself (i.e., the fraction of national income devoted to buying capital goods). In a data set that adjusts for price differences across countries (like the Penn World Tables), both these effects will show up as a higher investment rate. The effect that is being discussed in this paper is an additional effect once one controls for the overall real investment rate.
for growth is Lee (1995). Lee considers a cross country growth regression with several explanatory variables that include the total investment rate and the ratio of investment in imported machinery to investment in domestically produced capital goods (both equipment and non-equipment), the latter being the variable of interest. He obtains his series on domestically produced capital goods by subtracting imported machinery from the total investment series. Therefore, his domestic capital goods includes both equipment and non equipment investment. He finds that the ratio of foreign machinery investment to domestic capital goods investment is positively correlated with growth.

However, a problem with Lee's study is that it is not possible to distinguish between his hypothesis that stresses the importance of imported equipment and that of DeLong and Summers (1991) who emphasize the importance of overall equipment investment (both imported and domestically produced). The major finding of the DeLong and Summers paper is that equipment investment has a substantially higher effect on growth than non-equipment investment. The major portion of equipment investment in LDCs is imported. Therefore, his domestic capital goods investment variable includes mostly non-equipment investment (his foreign machinery variable, of course, includes only equipment). The positive coefficient estimate of the ratio of foreign machinery to domestic capital goods variable in his regression may be reflecting the difference between equipment and non-equipment investment rather than the difference between imported and domestic capital goods.

In this paper, in order to correct the problem with Lee's study, we distinguish between equipment investment that is domestically produced and that which is imported. We use panel data for a sample of less developed countries and use Least Squares With Dummy Variable (LSDV) estimation. We find that growth is negatively related to investment in domestically produced equipment and positively related to investment in imported equipment.
The remainder of the paper is organized as follows. Section 2 provides a simple model that is used to derive the equation to be estimated. Section 3 describes the data and discusses various econometric issues. Section 4 presents the results. Section 5 concludes.

2. THEORY

Consider a less developed economy that has three sectors- a consumption goods sector $X$ and two capital goods sectors. The two capital goods sectors are a non-equipment sector $Y$ and an equipment sector $Z$. The consumption goods sector and the equipment sectors are tradeable sectors while the non-equipment sector is non-tradeable. We will assume that this economy has a comparative advantage in the consumption goods sector and a comparative disadvantage in the equipment sector. We will treat the consumption good as the numeraire. We will assume that all markets are perfectly competitive and trade is balanced. We will assume that there is no international capital mobility so that the investment of the economy has to equal its savings.

We will assume that the production function in all three sectors is Cobb-Douglas and that the capital-labor intensities are the same in all sectors. The production function in all three sectors is as follows

\[ Y_i = A_i L_i^{1-b_i} K_{1i}^{b_i} K_{2i}^{(1-b_i)} \]  

for $i = x; y; z$

‘$A$’ is the productivity parameter, $L$ is labor, $K_1$ is non equipment capital and $K_2$ is equipment capital. Since the capital-labor intensities are the same across sectors, in equilibrium, the capital labor ratios will be the same in all sectors if they face the same wage and rental rate. Therefore, the relative prices between the sectors will be
determined by the productivity parameter $A$ (see Appendix 1).

The country has an import quota on equipment imports. Imported equipment is perfectly substitutable for domestically produced equipment. The quota is binding so that the demand for imported equipment exceeds supply. The domestic relative price of the imported variety (the consumption good is the numeraire) will equal the price of the domestically produced variety. The difference between the free trade price of equipment and the domestic price is the quota rent accruing to whoever is lucky enough to get the quota licenses. We assume that these licenses are allocated to domestic citizens.

Per capita national income $y$ at domestic prices in the absence of trade is given by the following expression

$$y = x + p_y y + p_z z$$

Here, $x$, $y$, and $z$ are the per capita quantities produced of the three goods and $p_y$ and $p_z$ are the domestic relative prices of goods $y$ and $z$.

When there is trade and some amount of the $z$ good (equipment) is imported then we have an additional term in the expression. This additional term arises from the fact that some amount of the $x$ good is exported and some amount of equipment is imported. If $i_m^z$ is the per capita quantity of equipment that is imported then the amount of $x$ that has to be exported in order to pay for the import (since trade is balanced) is $p_z^e i_m^z$, where $p_z^e$ is the world price of the $z$ good. Therefore, this term has to be subtracted from $x$ in the expression above. In exchange, the amount $i_m^z$ is imported which at domestic prices is valued at $p_z i_m^z$. This term has to be added to the expression above. Therefore, when there is trade the expression above changes to the following

$$y = x + p_y y + p_z z + (p_z - p_z^e) i_m^z$$

The fourth term on the right hand side of the equation above represents the quota rents since it is the difference between what producers pay for the equipment and
what they sell it at in the country. If the domestic and the world prices of equipment
are the same then this term is equal to 0. However, when the domestic price is greater
than the world price quota rents are positive.

At domestic prices the per capita national income of the country in terms of the
numeraire can be expressed as follows

\[ y = A x k_{1}^{b} x k_{2}^{(1-b)} \circ + (p_{x} - p_{x}^{w})i_{2} \]  \hspace{1cm} (4)

where, \( k_{1} \) and \( k_{2} \) are per capita non-equipment and equipment capital, respectively.
\( p_{x} \) and \( p_{x}^{w} \) are the domestic and world prices of equipment. \( i_{2} \) is the quantity of per
capita equipment imports. The first term is the value of total production in the
country in terms of the numeraire valued at domestic prices. It is equal to the sum
of the first three terms on the right hand side of equation (3) (see Appendix, A.1). The second term is the additional income in the form of quota rents.

A diagrammatic representation of quota rents and national income in terms of the
production possibility frontier (ppf) is shown on Figure 1 (where we have only two
goods, for simplicity). The line \( DD_{0} \) is the ppf. The slope of this line (absolute value)
is equal to the domestic relative price of equipment (in terms of the consumption
good). The country produces the bundle represented by \( P \). The line \( TT_{0} \) is the
budget line of the country when national income is valued at world prices. The slope
of the line is equal to the world price of equipment. The world price of equipment
is lower than the domestic price. If it trades with the rest of the world then it has
to operate on \( TT_{0} \). The country consumes the bundle \( C \). That is, it exports some
consumption goods in exchange for equipment. The value of this consumption at
domestic prices has to equal the value of its income at domestic prices. The budget
line representing this level of income is \( QQ_{0} \). The distance \( QD \) is the quota rent.
National income comes from four sectors - the three goods as well as a trading sector
that exports some of the consumption goods and imports equipment at world prices.
but sells it in the economy at higher domestic prices. The quota rent represents the gains from trade (as shown on the graph).

We will assume that the savings rates are exogenous. Let the savings rates (at domestic prices) in the two kinds of capital - equipment and non-equipment be \( s_1 \) and \( s_2 \), respectively. We will assume that the quota is equal to a constant fraction ‘\( q \)’ of \( i_2 \) or total per capita equipment investment. Then the savings rate in imported equipment, \( s_2^m \), is equal to \( qs_2 \). We will assume that non-equipment capital depreciates at the rate \( \pm_1 \), and all equipment capital depreciates at the rate \( \pm_2 \). Our assumptions imply

\[
i_2^m = qi_2 = \frac{qs_2y}{p_z}
\] (5)

Therefore, using equations (4) and (5), we have

\[
y = A_xk_b^b k_2^{b^2} \frac{1}{1 \ i \ \frac{p_2 \ p_z}{p_z}}
\] (6)

The equations of motion of the two kinds of capital are

\[
k_i = \frac{s_iy}{p_i} \ i \ \pm k_i
\] (7)

for \( i = y \text{(or} 1); z \text{(or} 2) \).

In the steady state we will have

\[
s_iy^S = p_i \pm k_i^S
\] (8)

for \( i = y \text{(or} 1); z \text{(or} 2) \).

Using equations (6) and (8) and taking logs we get an expression for the log of the steady state \( y \) which is as follows

\[
\log y^S = \frac{1}{1 \ i \ \frac{p_1}{p_1}} \ \log A_x + \frac{b^b}{1 \ i \ \frac{p_y}{p_z}} \ \log \frac{\tilde{A}}{s_1} + \frac{b^{b^2}}{1 \ i \ \frac{p_2}{p_z}} \ \log \frac{\tilde{A}}{s_2} + \frac{1}{1 \ i \ \frac{p_1}{p_2}} \ \log \frac{\tilde{A}}{s_2} + \frac{1}{1 \ i \ \frac{p_y}{p_z}} \ \log \frac{\tilde{A}}{s_2} + \frac{p_z}{p_z} \ qs_2
\] (9)
The last term, related to quota rents, captures the level of efficiency of this economy. The greater is the amount of imports, the higher are the quota rents. The quota rents represent the gains in income that come about as a result of trade. In this economy with no money and balanced trade, quota rents arise because the traders export the consumption good in exchange for imported equipment. The producers of the consumption good are paid in terms of the investment goods at prevailing domestic prices which is lower than world prices. The difference between what producers of the consumption good get and what the traders have obtained on the world market is the quota rent. This also is equal to the gains from trade because it is equal to the difference between the world price and the domestic rate of transformation (which is equal to the domestic price). Therefore, higher is the level of the quota, the greater will be the level of income in this country.

Equation (9) gives an expression for steady state capital stock when income and savings rates are being measured at domestic prices. The Penn World data set computes these variables at international prices. Since we are going to use this data set in our regressions, it will be useful to find an expression for the steady state \( y \) when all variables are measured in terms of international prices. This expression is given below.

\[
\log y^{*s} = \frac{1}{1 - \beta} \log A_x + \beta \log \frac{s^n_I}{p^{*e}_y} + (1 - \beta) \log \frac{s^n_I}{p^{*e}_z} + \log 1 + \frac{(p^{*e}_z - p^{*e}_z)(1 - \beta) s^n z}{p^{*e}_z} 
\]  

Equation (10)

The asterisk denotes that the variables are being measured at world prices. The expression looks very similar to the previous one except that the savings rates are now measured in international prices and the prices are international prices. Also, the last term has been altered. The expression \((1 - \beta) s^n z\) is the investment rate in domestic equipment valued at international prices. Production of domestic equipment reduces income at world prices since production of consumption goods is reduced to produce domestic equipment at a rate that is higher than the world price of equipment. The
greater is the production of domestic equipment, lower is income at world prices. This is the counterpart to the quota rents when income is valued at world prices than at domestic prices. The economy is more efficient is the sense of making more goods available when it is producing closer to its comparative advantage. Figure 1 shows a comparison of the two methods of measuring national income (at domestic prices vs. at world prices) in terms of the ppf. As was mentioned before, \( QQ^0 \) represents income at domestic prices while \( TT^0 \) represents income at world prices. As one can see on the graph, the difference between the domestic price and the world price leads to both the quota rents (when income is being measured at domestic prices) and the income loss due to lower efficiency (when income is being measured at world prices). The segment \( DT \) represents the efficiency loss resulting from the production of equipment, when income is measured at world prices. The expression for per capita national income when valued at world prices as well as the derivation of equation (10) are in Appendix 1 (A.2).

Using the expression for the steady state income in equation (10), we can derive an expression for the growth rate (see Barro and Sala-i-Martin 1995), when all variables are measured at world prices. It is as follows:

\[
\log \frac{y_t^w}{y_0^w} = K_1 + \frac{b}{1_i} C \log s_1^w + \frac{(1-b)}{1_i} C \log s_2^w + \frac{1}{1_i} C \log \left(1 + \frac{(p_z - p^z)}{p^z_s} (1 - q) s_2^w i \right) C \log y_0^w
\]

(11)

In the equation above \( y_0^w \) is initial income, \( K_1 \) is a collection of constants and \( C = (1_i e^{i \cdot t}) \).

Taking a first order Taylor approximation of the fourth term in the equation (11) around \((1_i q)\) equal to 0, we get,

\[
\log \frac{y_t^w}{y_0^w} = K_2 + \frac{b}{1_i} C \log s_1^w + \frac{(1-b)}{1_i} C \log s_2^w + \frac{1}{1_i} C \left( \frac{p_z - p^z_s}{p^z} s_2^w (1 - q) i \right) C \log y_0^w
\]

(12)

Equation (12) is the equation to be estimated. The exogenous variable of interest is
\( s_2(1\sqrt{q}) \) which is the fraction of income (at international prices) spent on domestically produced equipment or the investment rate in domestically produced equipment. If the domestic price of equipment is higher then the coefficient on \( s_2(1\sqrt{q}) \) should be negative and a higher \( s_2(1\sqrt{q}) \) will lead to lower growth. A lower \( s_2(1\sqrt{q}) \) acts like an improvement in the country’s level of technology. An improvement in the technology increases income directly but it has an increase in the growth rate because a higher capital stock can be sustained in the steady state. The basic intuition behind why a reduction in the production of domestic equipment or an increase in the investment rate in imported equipment will increase growth rates is the following. It acts like an increase in the level of technology. This by itself would not increase the growth rate. It would increase the level of income in all time periods without raising the growth rate. The increase in the growth rate come about because of increased capital accumulation. Capital accumulation results from the difference between the capital goods bought with the savings and that required to replenish the depreciated capital stock. Therefore, higher is the level of income, larger will be savings and therefore capital accumulation and growth.

3. DATA AND ESTIMATION ISSUES

Data

The data on gdp, investment and other macroeconomic variables were obtained from the Penn World Table 5.6 compiled by Summers and Heston (see Summers and Heston 1991, and K ravis, K enessey, Heston and Summers 1975 for details) . This data set also contains investment data at a disaggregated level on the five components of investment - machinery, transportation equipment, business construction, residential construction and other construction. The data on machinery constitutes my equipment data. The Summers and Heston data set also provides data on aggregate
investment as mentioned before. Due to differences in the method of computation, the disaggregated series do not add up to the aggregate series.

The data on gross domestic product and the disaggregated investment series are in 1985 international prices which makes the data comparable across countries. International prices are, roughly speaking, weighted averages of the price levels of the countries of the world. The weights are proportional to the GDP of the different countries. Therefore, the international price level is close to the price levels prevailing in the rich countries of the world. The average price level of GDP of my high income sample was around 112 (international price level = 100) while the average price level of investment was 99. On the other hand, the average price level of GDP of my LDC sample was around 53 while the average price level of investment was 72.

The data on imported machinery were obtained from OECD International Trade by Commodities Statistics. It contains data on machinery exports of OECD countries to all other countries. Since almost all of machinery imports of less developed countries comes from the high income nations which belong to the OECD, the data on total machinery exports of all OECD countries to a less developed country will be a good measure of the country’s machinery imports. The data is appropriate for the issue we are really interested in and that is whether or not developing countries benefit from machinery imports from developed nations since they embody technology, are of higher quality etc. The data are in current U.S. dollars. We assume that the data on imported machinery are at current international prices since the price level of the machinery imports will be close to the price level of the rich nations and therefore to the international price level.

The fraction \( s^2(1 - q) \) or the proportion of income spent on domestically produced equipment is obtained by taking the difference between the ratio of real equipment investment to real GDP (real values are at 1985 international prices) and the ratio of imported machinery to GDP at current (international) prices. For my LDC sample,
we selected all less developed countries for which data on both equipment investment and imported machinery were available for most years in the sample period\textsuperscript{2}. My sample period is 1970-1990. We chose this period because data were missing for quite a few years for many LDCs before and after this period. The high income sample includes all countries that are classified as high income countries by the World Development Report except the oil producing countries and countries are considered to be developing if they are classified as such by the United Nations or by their own governments.

Estimation

One problem with applying OLS to equation (12) is the constant term may differ across countries. The constant term includes the productivity parameter which is very likely to differ across countries. It may capture the effects of differences in technology, institutions, resource endowments (see Islam 1995). Also, it will be correlated with the regressors which include the investment rate. A better technology will increase the rate of return from investment and therefore increase the investment rate. If we impose the restriction that the constant term is the same across countries then there will be an omitted variable bias which will lead to biased and inconsistent estimators.

Another problem associated with this data may be measurement error. The investment rate in domestically produced equipment turns out to be negative for a few countries. This may be due to mismeasurement of equipment investment for some countries. It is less likely that the import data is mismeasured since it is based on customs data which is more reliable. If one makes the assumption that for any given country the extent of mismeasurement is the same in all periods then it can be subsumed under the constant term which is different across countries but the same for

\footnote{A few countries had to be dropped because their investment rates in domestic equipment were negative which is most probably due to measurement error.}
all periods for any given country\textsuperscript{3}.

The country specific term will be correlated with the regressors because it includes the productivity term, as mentioned before and also because of the measurement error. Therefore, one should use a fixed effects model and estimate equation (12) using Least Squares with Dummy Variables (LSDV).

4. RESULTS

LDC Sample

Before discussing the regression results it is useful to check whether some of the other implications of the theory hold. According to the theory quota restrictions increase investment in domestic equipment which in turn reduces the growth rate due to inefficiencies in the allocation of resources. Therefore, there should be a positive relationship between the extent of quota restrictions and the investment rate in domestic equipment. An absence of any relationship between the two would suggest something else was going on, even if growth rate was found to be negatively related to the investment rate in domestic equipment. Unfortunately, time series data on non tariff barriers is not available. However cross section data on non tariff barriers (NTB) on intermediate and capital goods is available in the Barro and Lee data set. Table 1 provides the results of OLS regression of investment rate in domestic equipment on the Barro-Lee non tariff barrier measure. The non tariff barrier measure turns out to be positive and strongly significant. The investment rate in domestic equipment would of course depend on other factors like the overall investment rate. Inclusion of the overall investment rate in the same regression reduces the estimate of the

\textsuperscript{3}The few countries that have negative domestic equipment investment rates have negative rates, which do not vary much, for all the periods under consideration suggesting that the extent of mismeasurement stays more or less the same across time.
coefficient of the quota measure dramatically but it continues to be significant at the 5% level.

Table 2 reports the results of the regressions using equation 12 with the investment rate in domestic equipment as the independent variable of interest. We use panel data with country and time dummies. In regression 1 we have equipment investment rate, non equipment investment, initial income and the investment rate in domestic equipment as independent variables. The coefficient estimate of the domestic equipment investment rate is negative as the theory would predict. It is also significant at the 5% level. The estimate is very high. It implies that an increase in the investment rate in domestic equipment by 1 percentage point decreases growth rate by almost 1.2 percentage points. The estimates imply that domestic equipment is about 17 times more expensive than imported equipment. Note that the coefficient for the equipment investment variable is positive and significant while the coefficient for the non equipment investment variable is small and insignificant. This is consistent with the DeLong and Summers result.

An obvious omitted variable that may be correlated with the variable of interest in this paper is some measure of openness. A higher degree of trade may lead to higher growth simply because of other reasons (e.g., new ideas resulting from interaction with other countries etc.) The second column reports the results of the regression with the trade share as an additional right hand side variable. The domestic equipment rate continues to be significant and the trade share is insignificant. It is interesting to compare the results of this regression with one which has the trade share as an

---

4 These results are not sensitive to the inclusion of Botswana. The discovery of diamonds in Botswana led to large equipment investment which tends to bias the coefficient of equipment investment upwards (see DeLong and Summers 1991).

5 This estimate is obtained by dividing the estimated coefficient of the domestic equipment variable by the sum of the coefficients of the log of equipment and log of non equipment investment variables and adding 1 (see equation 12).
independent variable but does not have the domestic equipment rate on the right hand side. Regression 3 in the fourth column reports the results of this regression. The trade share is positively and significantly related to growth. Since the inclusion of the domestic equipment rate makes the trade share variable insignificant (Reg 2), this suggests that the positive relationship between growth and openness (captured by the trade share) is mainly because of equipment imports. This, in our opinion, gives us a better understanding of how openness can affect the growth processes of developing countries.

Another reason why there may be a spurious correlation between growth and the domestic equipment rate is because of balance of payments constraints. If an economy is not performing well, it is likely that it will run into balance of payments difficulties as a result of which it may not be able to import goods including equipment. In the regression 4 in this table we have included two measures that will reflect balance of payments constraints - the average exchange rate and the balance of payments premium (the difference between the official exchange rate and the market exchange rate; this data is also obtained from the Barro-Lee data set). This regression also includes the trade share as well as the import share (in case imports have a greater effect on growth than trade in general). The domestic equipment rate continues to be significant although the size of the coefficient decreases somewhat. In regression 5, we also included the share of direct foreign investment in GDP as an additional control variable. It is possible that direct foreign investment may be correlated with machinery imports and growth may increase due to the transfer of (disembodied) technical knowledge resulting from the foreign investment and not because of machinery imports per se. The domestic equipment rate continues to be negatively and significantly related to growth (although at the 10% level). Since the first five regressions do not directly test the hypothesis that imported equipment is superior, we have included the investment rate in imported equipment instead of the investment rate in
domestic equipment in the last regression in this table. As expected, the coefficient of the imported equipment variable is positive and significant.

High Income Sample

The theory predicts that we should observe this result for less developed countries but not for developed nations since the latter have a comparative advantage in equipment. Table 3 reports the results of the regression for a sample of developed nations. The first column includes all the countries in the high income sample. In the first regression while the domestic equipment variable is not significant at the 5% level it is significant around the 10% level. In the second regression we include the trade share and the domestic equipment variable becomes significant at the 5% level and the coefficient is negative. This appears to cast some doubt on the theory. However, one can question the assumption that all the countries in the sample have a comparative advantage in equipment production. In particular, the assumption that Ireland has a comparative advantage in equipment production is probably false. Ireland was one of the poorest of the high income nations during this period. Therefore, one should check how sensitive these results are to the inclusion of Ireland. The third column reports the results of the regression without Ireland. One can see that there is a dramatic decrease in the absolute value of the estimate for domestic equipment investment. The absolute value drops from 0.42 to 0.28. The t-statistic also drops substantially and the variable is no longer significant. The estimates of the other investment variables also decrease but only very little and the t-statistics are not affected much. This is also what one would expect since the other investment variables should affect growth positively regardless of whether the country is developed or underdeveloped.

One could criticize the results for both the LDC sample as well as the sample with high income countries on the grounds that these right hand side variables are
Productivity differences across countries that may lead to a spurious correlation will be captured by the fixed effects and therefore will not lead to a bias in our estimates. However, productivity shocks within a country over different time periods may lead to a spurious correlation between growth and the domestic equipment rate. Instrumental variable estimation would solve that problem. Valid instruments for the domestic equipment rate would be measures of trade barriers especially non-tariff barriers. Unfortunately, time series data on non-tariff barriers for a large enough sample of countries does not exist making IV estimation impossible. However, the other control variables in the regression like the balance of payments premium would capture some of the effects of these productivity shocks. Also, it is difficult to imagine how reverse causality would lead to a negative relationship between growth and the domestic equipment rate.

5. CONCLUSION

There seems to be evidence to support the claim that investment in domestic equipment reduces the growth rate for less developed countries. This is because it leads to a misallocation of resources (since LDCs have a comparative disadvantage in equipment production) which acts like a decrease in the level of technology. This reduces real income and therefore real investment (for any given savings rate) and growth. Also, the evidence suggests that openness affects growth mainly through equipment imports. For a sample of rich nations, there seems to be no evidence that investment in domestically produced equipment affects growth adversely. This is just as one would expect since developed countries have a comparative advantage in the production of equipment.
APPENDIX

A.1 Derivation of the first term in equation (4)

Using the fact that the marginal revenue product of labor has to be the same in all sectors, we get,

\[
A_x k_{1x}^{a_0} k_{2x}^{a_1} \beta^{a_2} = p_y A_y k_{1y}^{a_0} k_{2y}^{a_1} \beta^{a_2} = p_z A_z k_{1z}^{a_0} k_{2z}^{a_1} \beta^{a_2} \tag{13}
\]

Here \(k_{1i}^0\) and \(k_{2i}^0\) \((i = x, y, \text{and} z)\) denote the capital stock per worker in that industry and not per person in the economy. Using the fact the marginal revenue product of the two kinds of capital (equipment and non-equipment) will have to be the same across sectors, we get

\[
A_x k_{1x}^{a_0} k_{2x}^{a_1} \beta^{a_2} = p_y A_y k_{1y}^{a_0} k_{2y}^{a_1} \beta^{a_2} = p_z A_z k_{1z}^{a_0} k_{2z}^{a_1} \beta^{a_2} \tag{14}
\]

and,

\[
A_x k_{1x}^{a_0} k_{2x}^{a_1} \beta^{a_2} = p_y A_y k_{1y}^{a_0} k_{2y}^{a_1} \beta^{a_2} = p_z A_z k_{1z}^{a_0} k_{2z}^{a_1} \beta^{a_2} \tag{15}
\]

Dividing (13) by (14), we get,

\[
k_{1x}^0 = k_{1y}^0 = k_{1z}^0 \tag{16}
\]

Dividing (13) by (15), we get,

\[
k_{2x}^0 = k_{2y}^0 = k_{2z}^0 \tag{17}
\]

Using the information given by equations (16), (17) in equation (13), we get,

\[
A_x = p_y A_y = p_z A_z \tag{18}
\]

As one can see from equation (18), the domestic relative prices of the goods are determined by the level of technology in the three industries.
The gross domestic product (ignoring the trading sector) will equal the value of total output in terms of the numeraire and is given by the following expression

\[ Y = A_x k_{1x}^{q_1} k_{2x}^{q_2} L_x + p_y A_y k_{1y}^{q_1} k_{2y}^{q_2} L_y + p_z A_z k_{1z}^{q_1} k_{2z}^{q_2} L_z \]  (19)

where \( L_x, L_y, L_z \) denote the workers employed in the three industries.

Using (16), (17), (18) and (19), we get,

\[ Y = A_x k_{1x}^{q_1} k_{2x}^{q_2} L \]  (20)

where \( L = L_x + L_y + L_z \), is the total population of the economy. Since the capital labor ratios are the same in all industries \( k_{1x}^{q_1} \) and \( k_{2x}^{q_2} \), will equal \( k_1 \) and \( k_2 \), respectively. That is, the capital per worker ratio in each industry will equal the overall capital per worker for the economy as a whole. Dividing both sides of (20) by \( L \), we get,

\[ y = A_x k_{1x}^{q_1} k_{2x}^{q_2} \]  (21)

A.2 Derivation of equation (10)

When all variables are measured at world prices then the per capita gdp is given by the following expression

\[ y^w = A_x k_{1x}^{b_1} k_{2x}^{b_2} (p_z i_2) \]  (22)

where \( i_2 \) is the quantity of domestic equipment produced. Since the country has a comparative disadvantage in equipment, production of equipment reduces income at world prices (as shown on graph 2 and explained in section 2).

Now from equation (5) we get,

\[ i_2 = \frac{s_2 y(1 + q)}{p_z} \]  (23)
where $y$ is per capital national income at domestic prices and $s_2$ is the investment rate in equipment at domestic prices.

Using equations (6), (22) and (23) we get,

$$y^a = A x k_1^{b_1} k_2^{(1_2)} \frac{2}{4} \frac{1}{1} \frac{i_1}{i_2} \frac{(p_2 - p_1) s_2}{p_2} \frac{3}{5}$$

(24)

Or, using equations (6) and (24),

$$\frac{y}{y^a} = 1 + \frac{1}{1} \frac{i_1}{i_2} \frac{(p_2 - p_1) s_2}{p_2}$$

(25)

Now,

$$s_1^a = \frac{p_2 y_{i_1}}{y^a} = \frac{p_2 y_{i_1}}{y^a} = \frac{s_1 y}{y^a}$$

(26)

Here we have made the assumption that the domestic and world relative price of non-equipment are the same.

Also,

$$s_2^a = \frac{p_2 y_{i_2}}{y^a} = \frac{p_2 s_2 y}{y^a p_2} = s_2 \frac{p_2^a}{y^a}$$

(27)

Using equations (25), (26) and (27), we get the following three relationships

$$y = y^a \left(1 + \frac{(p_2 - p_1) s_2}{p_2^a}\right)$$

(28)

and,

$$s_1 = \frac{s_1^a}{1 + \frac{(p_2 - p_1) s_2}{p_2^a}}$$

(29)

and,

$$s_2 = \frac{p_2}{p_2^a} \frac{s_2^a}{1 + \frac{(p_2 - p_1) s_2}{p_2^a}}$$

(30)

Substituting $y$, $s_1$ and $s_2$ in equation (9) for the expressions in the three equations given above we get equation (10).
LIST OF COUNTRIES

LDC Sample
Argentina
Botswana
Colombia
Dominican Republic
Greece
Guatemala
Honduras
Hong Kong
India
Israel
Jamaica
Kenya
Korea (South)
Malawi
Mauritius
Mexico
Nepal
Panama
Paraguay
Peru
Philippines
Poland
Sri Lanka
Swaziland
Taiwan
Thailand
Turkey
Venezuela
Yugoslavia
Zimbabwe

High Income Sample
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany (West)
Iceland
Ireland
Italy
Japan
Netherlands
New Zealand
Norway
Spain
Sweden
Switzerland
United Kingdom
United States
REFERENCES


<table>
<thead>
<tr>
<th>TABLE 1 (24 LDCs)</th>
<th>Reg 1</th>
<th>Reg 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep var: average investment rate in domestic equipment (1965-1990)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non tariﬀ measure</td>
<td>0.47**</td>
<td>0.014**</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>overall investment rate</td>
<td></td>
<td>0.075*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.039)</td>
</tr>
</tbody>
</table>

Standard errors are in parentheses; ** denotes that the variable is signiﬁcant at the 5% level. * denotes variable is signiﬁcant at the 10% level.
<table>
<thead>
<tr>
<th>TABLE 2 (30 LDCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep var: 5 yr avg. growth rate</td>
</tr>
<tr>
<td>(includes country and time dummies)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reg 1</th>
<th>Reg 2</th>
<th>Reg 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>log of equipment investment rate</td>
<td>0.07**</td>
<td>0.067</td>
</tr>
<tr>
<td>(0.018)</td>
<td>(0.018)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>log of non-equipment investment rate</td>
<td>0.004</td>
<td>-0.008</td>
</tr>
<tr>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>domestic equipment investment rate</td>
<td>-1.19**</td>
<td>-1.03**</td>
</tr>
<tr>
<td>(0.42)</td>
<td>(0.43)</td>
<td></td>
</tr>
<tr>
<td>imported equipment investment rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log of initial income</td>
<td>-0.07**</td>
<td>-0.079**</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>trade share</td>
<td>0.0005</td>
<td>0.0009**</td>
</tr>
<tr>
<td>(0.0003)</td>
<td>(0.0003)</td>
<td></td>
</tr>
<tr>
<td>import share</td>
<td></td>
<td></td>
</tr>
<tr>
<td>exchange rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>balance of payments premium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>direct foreign investment share</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R² (adjusted) | 0.72 | 0.73 | 0.67

Standard errors are in parentheses; ** denotes that the variable is significant at the 5% level. * denotes that the variable is significant at the 10% level.
TABLE 2 (continued)

Dep var: 5 yr avg. growth rate
(includes country and time dummies)

<table>
<thead>
<tr>
<th></th>
<th>Reg 4</th>
<th>Reg 5&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Reg 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>log of equipment investment rate</td>
<td>0.06**</td>
<td>0.067**</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.021)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>log of non-equipment investment rate</td>
<td>-0.015</td>
<td>-0.005</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.019)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>domestic equipment investment rate</td>
<td>-0.92**</td>
<td>-1.02*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.45)</td>
<td>(0.54)</td>
<td></td>
</tr>
<tr>
<td>imported equipment investment rate</td>
<td></td>
<td></td>
<td>1.7**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.57)</td>
</tr>
<tr>
<td>log of initial income</td>
<td>-0.09**</td>
<td>-0.085**</td>
<td>-0.06**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.025)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>trade share</td>
<td>0.002</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td></td>
</tr>
<tr>
<td>import share</td>
<td>-0.004</td>
<td>-0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.0036)</td>
<td></td>
</tr>
<tr>
<td>exchange rate</td>
<td>-0.000015</td>
<td>-0.00001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00001)</td>
<td>(0.000018)</td>
<td></td>
</tr>
<tr>
<td>balance of payments premium</td>
<td>-0.00003</td>
<td>-0.00012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000075)</td>
<td>(0.000011)</td>
<td></td>
</tr>
<tr>
<td>direct foreign investment share</td>
<td>0.236</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.24)</td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt; (adjusted)</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Standard errors are in parentheses; ** denotes that the variable is significant at the 5% level. * denotes that the variable is significant at the 10% level. <sup>1</sup>Excludes Hong Kong and Poland.
<table>
<thead>
<tr>
<th></th>
<th>Reg 1</th>
<th>Reg 2</th>
<th>Reg 3&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>log equip. inv.</td>
<td>0.017</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.016)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>log non-equip inv.</td>
<td>-0.002</td>
<td>-0.003</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>domestic equip inv.</td>
<td>-0.316*</td>
<td>-0.42**</td>
<td>-0.28</td>
</tr>
<tr>
<td></td>
<td>(0.189)</td>
<td>(0.20)</td>
<td>(0.24)</td>
</tr>
<tr>
<td>log initial income</td>
<td>-0.102**</td>
<td>-0.11**</td>
<td>-0.114**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>trade share</td>
<td></td>
<td>-0.0003</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0002)</td>
<td>(0.0002)</td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt; (adjusted)</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Standard errors are in parentheses; ** denotes that the variable is significant at the 5% level. * denotes that the variable is significant at the 10% level. <sup>1</sup> Excludes Ireland.
Fig. 1.