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Why Does the Productivity of Investment Vary Across Countries?

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ABSTRACT

A country's growth of output is identically equal to its ratio of investment to output and the productivity of investment. In 'new' growth theory regressions, which include the investment ratio, all other included variables pick up why the productivity of investment differs between countries. This paper converts a 'new' growth theory regression equation into productivity of investment equation which allows for the direct testing of the diminishing returns to capital hypothesis of neoclassical growth theory, and to identify the major determinants of differences in the productivity of investment using the general-to-specific model selection algorithm – Autometrics. Nineteen explanatory variables are considered, and export growth, property rights, latitude, and education turn out to be the most important. Eighty-four countries are taken over the period 1980-2011. There is no evidence of diminishing returns to capital across countries, so investment matters for long run growth.

Key Words: 'new' growth theory; productivity of investment; cross-country growth regressions.

JEL Codes: 011, 040, 047

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NON-TECHNICAL SUMMARY

'New' (endogenous) growth theory seeks to explain growth rate differences between countries outside the confines of orthodox neoclassical growth theory, but also to rehabilitate the neoclassical model with diminishing returns to capital by introducing other variables into the equations to explain why there has not been unconditional convergence of per capita incomes across the world as predicted by the basic neoclassical (Solow) growth model. It is argued that because output growth is by definition equal to a country's ratio of investment to GDP times the productivity of investment, if the investment ratio is included in a new growth theory equation, all that new growth theory is doing is testing for why the productivity of investment differs between countries. But the productivity of investment is never treated as the dependent variable. It is easy to do so, however, by dividing the whole equation by the investment ratio. This has the added advantage of being able to test directly the hypothesis that the productivity of investment falls as investment rises and as countries get richer (the neoclassical assumption of diminishing returns to capital), without relying on the sign on the initial per capita income variable, a negative sign on which could be the result of catch-up or faster structural change in poor countries than rich and not diminishing returns. The model is tested using the general-to-specific model selection algorithm, Autometrics, taking a sample of 84 countries over the period 1980-2011 and 19 different independent variables that have been highlighted in the growth literature. Nine of the independent variables turn out to be significant, the most important of which turn out to be export growth; education; latitude, and political rights. There is no evidence of diminishing returns to capital i.e. that the productivity of investment in rich countries is lower than in poor countries.

Introduction

In his famous paper 'An Essay in Dynamic Theory', Harrod (1939) expressed a country's actual growth rate as the ratio of how much it saves as a proportion of national income (s) and its actual incremental capital-output ratio (c) which includes changes in the level of inventories. i.e.

$$g = s/c \tag{1}$$

where s = S/Y and c = ΔK/ΔY = I/ΔY. Since savings equals investment in the national accounts, equation (1) is true by definition. Equally, a country's growth rate may be expressed as the product of how much it invests as a proportion of national income and the productivity of investment. i.e.

$$g = \frac{I}{Y} \cdot \frac{\Delta Y}{\Delta K} = \frac{I}{Y} \cdot \frac{\Delta Y}{I} \tag{2}$$

where I/Y is the investment ratio and ΔY/ΔK is the productivity of investment (and the reciprocal of the capital-output ratio in equation (1) when S=I). If the productivity of investment was the same across countries, there would be a perfect correlation between the growth of countries and the proportion of national income invested. To the extent that there is not a perfect correlation, this must be the result of differences in the productivity of investment.

The purpose of this article is threefold: firstly to show that there are large differences in the productivity of investment across countries; secondly to test econometrically the possible causes of differences in the productivity of investment using explanatory variables commonly used in the growth literature, and thirdly to test the orthodox neoclassical assumption of diminishing returns to capital which, if true, would mean that investment does not matter for long run growth. We can say in advance that the assumption of diminishing returns to capital is not supported by the evidence. The productivity of investment is as high, if not higher, in rich countries as in poor countries. We take for analysis a sample of 84 developed and developing countries over the period 1980-2011. Nineteen potential determinants of productivity differences are considered using the general-to-specific model selection algorithm of Autometrics (Krolzig and Hendry, 2001). This is an important, but under-explored, topic with policy implications for countries which wish to improve their growth performance on a sustainable basis. Before considering the empirics, however, let us consider what orthodox growth theory has to say about the role of investment in growth and the productivity of investment.

Orthodox Growth Theory: Old and 'New'

Orthodox growth theory is still based on the neoclassical theory of growth as first developed by Solow (1956) and Swan (1956). Neoclassical growth theory still dominates the economics textbooks and the teaching of economic growth across the world. How the model achieved the elevated status it has is still something of a mystery because most of its assumptions and predictions are manifestly false. There are three basic assumptions of the model, and three basic predictions. The first assumption is that the labour force and labour-augmenting technical progress (or labour productivity growth) grow at a constant exogenous rate, and these two variables determine the long run growth of countries. This is a supply-oriented model in which the level or pressure of demand for output plays no part. In practice, however, we know that the labour force responds to the pressure of demand through variations in participation rates of the labour force, hours worked and migration; and we know that technical progress is endogenous because investment responds to the pressure of demand which embodies technical change. New vintages of capital are more productive than older vintages. Harrod (1939) described the sum of labour force growth and technical progress (or labour productivity growth) as the natural rate of growth (g_n). But there is nothing natural about the natural rate of growth (Leon-Ledesma and Thirlwall, 2000). There is now ample research showing that the natural rate of growth is endogenous, not exogenous, responding to the actual growth rate (Leon-Ledesma and Thirlwall, 2000, 2002; Vogel, 2009; Libanio, 2009; Dray and Thirlwall, 2011).

The second basic assumption of the neoclassical growth model is that all saving is invested. There is no independent investment function. This assumption implies no long run deficiency of aggregate demand, ruling out long periods of secular stagnation with growth lower than its potential. It is a return to pre-Keynesian economics which assumes that the rate of interest is the price which equilibrates the supply and demand for saving. Keynes showed this to be false; it is changes in income that equilibrates savings and investment via the multiplier, and the rate of interest is the price which equilibrates the supply and demand for money.

The third assumption of the neoclassical growth model is that the function relating output to inputs is the so-called Cobb-Douglas production function in which the elasticities of output with respect to labour and capital are both less than unity; and the sum of the elasticities equals unity which implies constant returns to scale. Labour input, capital input and total factor productivity growth are all exogenously determined. The crucial assumption for the predictions of the model is that the elasticity of output with respect to capital is less than unity so that the marginal product of capital is assumed to fall as the capital-labour ratio rises i.e. diminishing returns to capital.

These assumptions lead to three basic predictions of the model. First, in the steady state of the model the *level* of per capita income will be positively related to the savings ratio of countries and negatively related to the growth of population. This prediction is generally supported (see Mankiw et al., 1992). Secondly, in the long run steady state, the *growth* of output per head (or living standards) is independent of the ratio of investment to national income because of the assumption of diminishing returns to capital. In the limit the marginal product of capital falls to zero. In the transition from one steady state to another, investment can raise the growth rate temporarily, but not the long run growth performance. This is determined by the growth of the labour force and labour productivity. The model begs the question, of course, of how long is the long run? Early theoretical simulation models (e.g. Atkinson, 1969; Sato, 1966) suggested a transition of anything between 50 and 80 years which brings to mind the quip of Keynes (1936) that in the long run we are all dead. It is in the present that we have our being, and current investment will matter for growth performance. How important investment is for growth is an empirical question that we examine later.

The third prediction of the neoclassical growth model is that because of diminishing returns to capital, poor countries should grow faster than rich countries, given the same tastes and preferences for saving and investment, and therefore there should be a convergence of per capita incomes across the world. Historically (see Milanovic, 2016; Bourgninon, 2015) we don't observe the convergence of living standards across countries as measured by the Gini ratio. In 1820, the international Gini ratio was approximately 0.2; today it is 0.5, and reached a peak of 0.54 in 2000. Why is this? Is it because savings and investment rates differ significantly between rich and poor countries (in which case the *unconditional* convergence of per capita incomes is not to be expected), or is the assumption of diminishing returns to capital false so that the marginal product of capital (or productivity of investment) is not higher in poor countries than rich countries. This is a matter that we explore later.

The lack of convergence of per capita incomes across the world gave rise in the 1980s to what has become to be known as 'new' growth theory or endogenous growth theory. 'New' models of economic growth, but building on orthodox supply-oriented theory, were pioneered by Romer (1986) and Lucas (1988) which attempted to explain why the productivity of investment does not necessarily fall as countries get richer and accumulate more capital per head. Romer argued that there are externalities to research and development (R&D) which keep the marginal product of capital from falling, while Lucas stressed the role of education and human capital formation. In fact, it is clear from the definition of the capital-output ratio that *anything* that raises output per head in the same proportion as capital per head will keep the capital-output ratio (or the productivity of investment) constant. The capital-output ratio may be written as:

$$\frac{K}{Y} = \frac{K}{L} \cdot \frac{L}{Y} \qquad (3)$$

where K/Y is the capital-output ratio; K/L is the capital-labour ratio, and L/Y is the labour input per unit of output (which is the reciprocal of labour productivity). It can be seen that anything that reduces labour input per unit of output in the same proportion as K/L increases will keep K/Y constant, including, for example, learning by doing, in addition to R&D and improvements in the quality of the labour force.

The simplest version of 'new' growth theory is the so-called AK model which assumes constant returns to capital i.e.

$$Y = AK \qquad (4)$$

where Y is output, K is capital (broadly defined) and A is a constant. On simple inspection it is obvious that this specification is the static analogue of the Harrod growth equation. Totally differentiating equation (4), and dividing by Y gives:

$$\frac{dY}{Y} = g = A\frac{dK}{Y} = A\frac{I}{Y} = \frac{s}{c} \qquad (5)$$

where I/Y = s is the savings-investment ratio and c = 1/A – the actual incremental capital-output ratio.

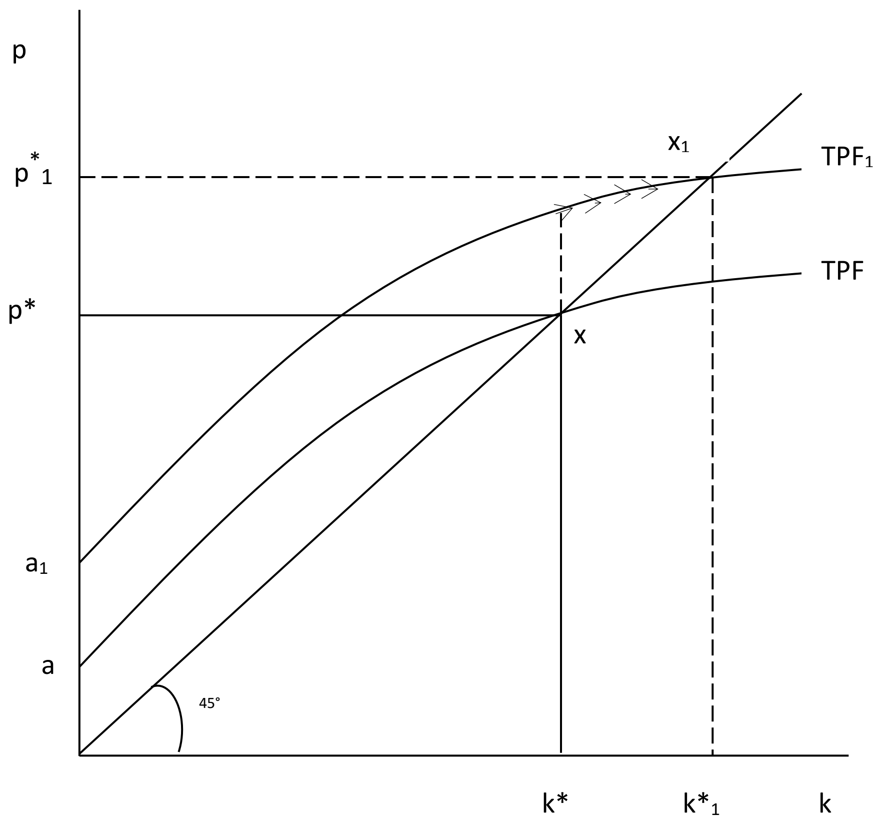
As a matter of historical interest, the 'new' growth theorists were not the first to explain why the productivity of investment may not decline as countries get richer and accumulate more capital per head. Nicholas Kaldor, the famous Hungarian/Cambridge economist (and bete noire of the neoclassical school) pointed out, many years prior, the rough constancy of the capital-output ratio as one of his so-called 'stylised facts' of economic growth that he sought to explain in models of economic growth developed in the late 1950s/early 1960s (Kaldor 1957,1961). We can quote Kaldor in full:

> As regards the process of economic change and development in capitalist societies, I suggest the following 'stylised facts' as a starting point for the construction of theoretical models - - - - -(4) steady capital-output ratios over long periods; at least there are no clear long-term trends, either rising or falling, if differences in the degree of capital utilisation are allowed for. This implies , or reflects, the near identity in the percentage rate of growth of production and the capital stock i.e. that for the economy as a whole, and over long periods, incomes and capital tend to grow at the same rate (Kaldor, 1961, p.178).

Kaldor’s explanation lay in his innovation of the technical progress function (TPF), to replace the neoclassical production function with its artificial distinction between movements along the function and shifts in the function, relating the growth of output per man (p) to the rate of growth of capital per man (k), the slope and position of which determines the long-run equilibrium growth of output. Consider Figure 1 below:

Figure 1

Kaldor’s Technical Progress Function



On the vertical axis, p measures the growth of output per man; and on the horizontal axis, k measures the growth of capital per man. The position of the TPF at ‘a’ gives the degree of autonomous technical progress (e.g. learning by doing) independent of capital accumulation, while the slope of the TPF measures the technical dynamism of a country. A flat slope indicates sluggishness, with capital accumulation leading to a slow rate of productivity growth, while a steep slope indicates a dynamic economy with capital accumulation embodying a significant degree of technical progress. Anywhere along the 45-degree line, the capital-output ratio is constant. At p*-k*, the economy is in equilibrium. Now suppose there is an upward shift of the TPF to TPF_1 , which raises output growth by more than capital accumulation, increasing the productivity of investment and raising the rate of profit. This induces an increase in the rate of capital accumulation to k_1* and restores the capital-output ratio at X_1, giving an equilibrium growth of output per man of p_1*. By contrast, if investment gets ahead of technical progress (e.g. a rise in k without an upward shift in TPF) the productivity of investment falls, the rate of profit falls, and investment is cut back. In other words, either way, capital accumulation adjusts to changes in technical dynamism preserving the rate of profit and the capital-output ratio. 'New' endogenous growth theory is precisely anticipated.

What applies to countries through time applies *pari passu* to different countries at a point in time, with differences in growth rates at the same capital-output ratio being associated with different technical progress functions ($p_1^* > p^*$). To quote Kaldor again (Kaldor, 1972, p.11-12):

> A lower capital-labour ratio does not necessarily imply a lower capital-output ratio – indeed, the reverse is often the case. The countries with the most highly mechanised industries, such as the United States, do not require a higher ratio of capital to output. The capital-output ratio in the United States has been falling over the last 50 years, while the capital-labour ratio has been steadily rising; and it is lower in the United States today than in the manufacturing industries of several developing countries. Technological progress in the present century led to a vast increase in the productivity of labour, but this was not accompanied by any associated reduction in the productivity of capital investment.

We shall give some evidence below which supports Kaldor's assertion that the productivity of investment is as high in rich countries as it is in poor countries.

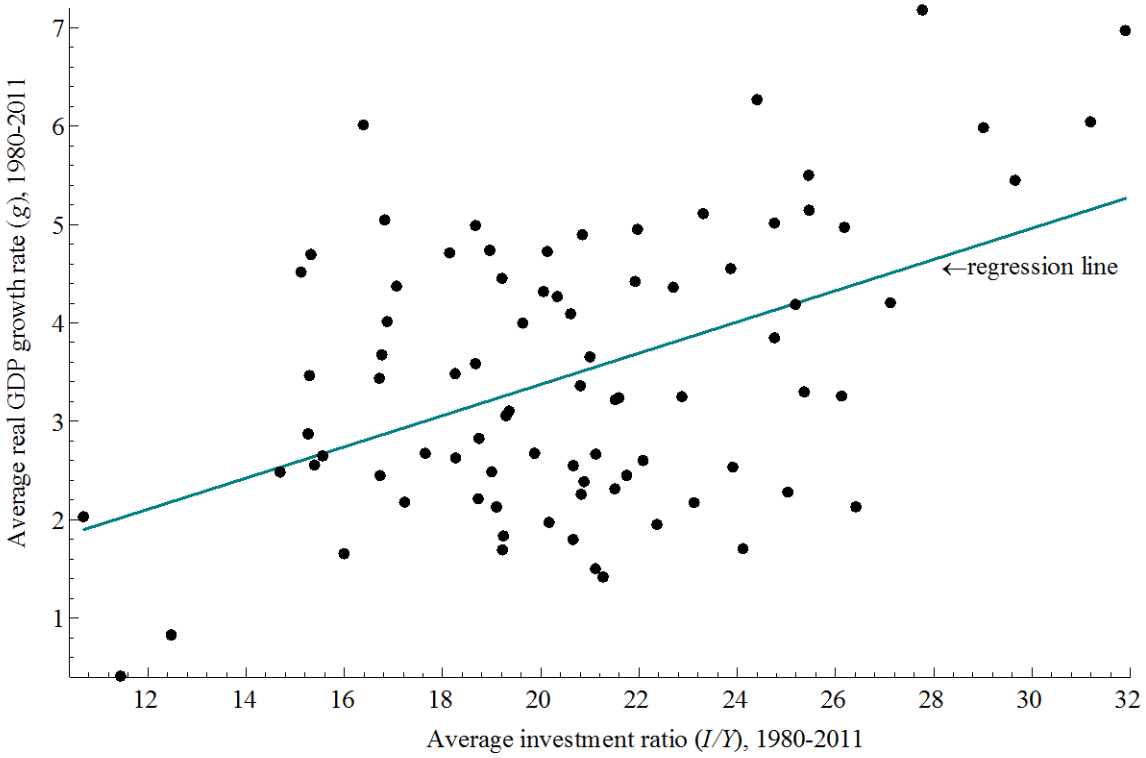
Investment and Growth, and 'New' Growth Theory

Now let us look at the evidence on the relationship between investment and economic growth. We take 84 rich and poor countries for which reliable data are available over the years 1980 to 2011, and plot the scatter diagram in Figure 2.

Average GDP growth is measured on the vertical axis and the average ratio of investment to GDP is measured on the horizontal axis. The scatter points show a rough positive relationship which is confirmed by the estimation of a simple cross-section regression equation which gives (t values in parentheses):

$$g = \underset{(0.28)}{0.20} + \underset{(4.79)}{0.16}\,(I/Y) \qquad (6)$$

Figure 2
Investment and Growth



Notes: 1) Data source: World Bank Development Indicators. 2) Figure 2 is scaled according to the lowest investment ratio in the sample, which is 10.7%.

The regression coefficient of 0.16 is statistically significant at the 99 percent confidence level, and implies an average productivity of investment across the sample of 16 percent. The coefficient of determination (R-squared), however, is only 0.22 which leaves a lot of the variance in the growth of output to be explained by differences in the productivity of investment. Taking account of population growth (p), and regressing the rate of growth of per capita income on the investment ratio, gives:

$$g\text{-}p = \underset{(-4.73)}{-2.64} + \underset{(7.94)}{0.21}\,(I/Y) \qquad (7)$$

Now the R-squared is 0.43 which leaves just over one-half of the variance in per capita income growth to be explained by differences in the productivity of investment.

The test of 'new' growth theory is to see whether there is convergence or divergence of per capita incomes across countries, and to run a simple regression (see Barro, 1991):

$$g\text{-}p = a + b(\textit{Initial PCY}) \qquad (8)$$

where g-p is the average growth of per capita income (PCY) over a period and *Initial PCY* is the log of the initial level of per capita income of countries. If b is significantly negative this is taken as signifying unconditional convergence (often referred to as beta convergence) explained by diminishing returns to capital. If b is not significantly different from zero (or positive), the hypothesis of unconditional convergence is rejected, and then researchers add other explanatory variables to test for *conditional* convergence to see whether the sign on the initial PCY turns negative when other factors are allowed for. Barro (1991) was one of the first to control for differences in education across a sample of 98 countries over the period 1960 to 1985, and found evidence for conditional convergence. The partial correlation between the rate of growth of per capita income and the initial level of PCY is -0.7 when differences in education are allowed for. Barro concludes: 'thus in a modified sense, the data support the convergence hypothesis of neoclassical growth models [based on diminishing returns to capital]. A poor country tends to grow faster than a rich country, but only for a given quantity of human capital' (p.409). Barro, and other 'new' growth theorists, are really neoclassical economists in disguise. Their models are still supply-oriented in which demand plays no part. The only difference from 'old' growth theory is that each country reaches its own steady-state level of per capita income and not a common level as in the original Solow model.

Other 'new' growth theorists add other variables to the basic equation (8) such as population growth; trade variables; government consumption expenditure; institutional and political variables, and *investment.* But it is clear from equation (2) that if the investment ratio is added as an explanatory variable, all the other variables must be picking up the productivity of investment. As Levine and Renelt (1992) perceptively remark: 'If we include INV [the share of investment in GDP in the equation] the only channel through which other explanatory variables can explain growth differentials is [through] the efficiency of resource allocation'; in other words, by differences in the productivity of investment.

Let us consider in more detail an augmented 'new' growth theory estimating equation of the form:

$$g\text{-}p = a + b(\mathit{InitialPCY}) + b_1(I/Y) + b_n(Z_n) \qquad (9)$$

where Z_n is a vector of other explanatory variables (where n is the number of other variables). What we are arguing is that if I/Y is in the equation, and we know by definition that $g = (I/Y)(\Delta Y/I)$, the other explanatory variables must be picking up the effect on $\Delta Y/I$ – the productivity of investment. But in 'new' growth theory the productivity of investment is never treated as a dependent variable. Moreover, and most important, a significant negative b coefficient in equation (9) cannot be taken as conclusive evidence of diminishing returns to capital because a negative sign is consistent first of all with faster structural change from low to higher productivity sectors in poor countries, and secondly with 'catch-up'. As Benhabib and Spiegel (1994) remark in their paper on human capital in development: 'a negative coefficient estimate on initial income levels may not be a sign of convergence due to diminishing returns, but of catch-up from adoption of technology from abroad. These two forces may be observationally equivalent in simple cross-country growth accounting exercises' (p.160).

Measuring the Productivity of Investment

These weaknesses in the 'new' growth theory empirical literature, and the interpretation of results, may be overcome by converting a 'new' growth estimating equation into a productivity of investment equation by dividing both sides of equation (9) by I/Y which gives:

$$\frac{g-p}{I/Y} = b_1 + a(I/Y)^{-1} + b\left(\frac{lnitialPCY}{I/Y}\right) + b_n\left(\frac{Zn}{I/Y}\right) \qquad (10)$$

There are many other ways of measuring the productivity of investment, but this is by far the simplest and the most consistent way for analysis across countries[2]. The variable on the left hand side of equation (10) is what we call the adjusted or net productivity of investment (adjusting for the contribution that population growth makes to output growth through the growth of the workforce).[3] The relationship between the net productivity of investment (nPOI)) and the inverse of the investment ratio $(I/Y)^{-1}$ provides a direct measure of the returns to capital. A positive sign indicates diminishing returns, and if 'a' is not significantly different from zero this would indicate constant returns to capital i.e. no relation between the quantity of investment relative to GDP and its productivity. The sign on the initial per capita income variable in equation (10) measures whether or not there is conditional convergence, but a negative sign can no longer be interpreted, as Barro (1991) does, as a rehabilitation of the neoclassical model with diminishing returns to capital because this has already been controlled for.

Descriptive Analysis

To test for diminishing returns to capital, and the determinants of the productivity of investment, we shall be basically running regressions of type equations (9) and (10), using the software Autometrics (Doornik and Hendry, 2013). We have assembled a consistent data set for 84 developed and developing countries which includes nineteen explanatory variables over the period

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[2] See Caselli and Feyrer (2007) for a survey.

[3] This is similar to Leibenstein's (1966) concept of the population-adjusted incremental capital-output ratio (or its reciprocal)

1980-2011. The precise definition of the variables, and the countries taken, are given in Appendix 1 and 2. Before econometric estimation, however, it is informative to look at the raw data on gross investment productivity and net (adjusted for population growth) investment productivity across the World Bank's income classification of countries in 2013: low income (LI); lower middle income (LMI); upper middle income (UMI), and high income (HI), and also across quartiles of countries from poorest to richest based on their initial level of per capita income in 1980. The results are given in Tables 1 and 2, together with the standard deviation of all the variables in parentheses.

The first data column in both Tables gives the average unadjusted or gross productivity of investment (POI); column 2 gives the average growth of per capita income (g-p); column 3 gives the average population-adjusted or net POI, and column 4 gives the average investment ratio (I/Y).

Table 1:
World Bank Income Classification (2013) and Capital Productivity

Income Classification (number of countries)	Gross POI (%)	$(g-p)$ (%)	Net POI (%)	I/Y (%)
LI (13 countries)	21.35 (7.92)	0.86 (1.44)	4.10 (9.58)	16.93 (3.46)
LMI (23 countries)	18.52 (6.32)	1.35 (1.49)	6.47 (7.50)	19.94 (4.23)
UMI (17 countries)	18.32 (4.14)	2.17 (1.26)	9.45 (4.45)	22.13 (3.93)
HI (31 countries)	13.10 (4.90)	2.07 (0.97)	8.91 (3.40)	22.16 (3.58)

Note: Standard deviations in parentheses.

Table 2:
Income Quartiles: Initial Per Capita Income Levels 1980

Income Classification (number of countries)	Gross POI (%)	$(g-p)$ (%)	Net POI (%)	I/Y (%)
Poorest quartile (21 countries)	22.05 (7.00)	1.38 (1.64)	6.54 (9.05)	18.03 (3.99)
Second poorest quartile (21 countries)	17.33 (5.32)	1.55 (1.60)	6.40 (7.44)	21.52 (4.72)
Second richest quartile (21 countries)	17.52 (4.17)	2.26 (1.23)	10.00 (4.14)	21.82 (4.36)
Richest quartile (21 countries)	10.75 (2.94)	1.64 (0.43)	7.76 (2.20)	21.34 (2.36)

Note: Standard deviations in parentheses.

Table 1 shows that the low income countries have a higher gross productivity of investment than high income countries, but this conclusion is reversed when population growth is allowed for. In the low income countries the adjusted productivity of investment is as low as 4 percent, whereas it is nearly 9 percent in the high income countries. But note that the standard deviations in the low- and middle-income countries are much larger than in the upper middle-income and high-income countries. Table 2 tells a similar story, except now the net productivity is more equal across low and high income countries. The richest quartile of countries has a productivity of 7.7 percent, and the poorest quartile has a productivity of 6.5 percent, but again the standard deviation in the poorest two quartiles are large relative to the richest two quartiles. Overall, this means that there is a large cross-section variation within the poorest countries and also across all countries.

If we further divide our sample of 84 countries into equal halves according to 1980 per capita income levels, and compare the productivity of investment in the poorest and richest countries, we get a net productivity of investment of 8.9 percent for rich countries and 6.5 percent for poor countries, with standard deviations of 3.5 percent and 8.2 percent in each half, respectively.

Overall, therefore, what the raw evidence shows is that while, on average, the net productivity of investment seems to be roughly equal across groups of countries, there is wide variation within groups of countries, and this is what we will try and explain with our econometric modelling. We can say in advance that there are a number of factors which are significant in explaining this wide variation in the net productivity of investment across rich and poor countries, but the econometric results reject the neoclassical hypothesis of diminishing returns to capital.

Determinants of the Productivity of Investment

Many factors determine a country's productivity of investment. We consider nineteen potential explanatory variables which we think might be important, and which have been used in the 'new' growth theory literature. A full list of regressors and their definition is given in Appendix 1. The education and skill of the workforce is likely to play an important role, so we include the average years of schooling at primary, secondary and tertiary level, and also interact education with the initial level of per capita income to test whether education helps a country to catch up at a faster rate. Institutional structures are likely to be important, and we measure the institutional framework by an index of political rights, and by the number of revolutions and coups within a country[4]. Trade can affect the productivity of investment in a number of ways. To compete in world markets the export sector needs to be competitive and dynamic. The growth of exports will affect the capacity utilisation of capital because a shortage of foreign exchange can push an economy into recession. We include as regressors a trade openness variable and the growth of exports. The structure of an economy will matter which we measure by the share of mining and quarrying in GDP. Latitude and

[4] We also used a rule of law index (Barro,1998) for a smaller sample of 79 countries, but it was eliminated in the model reduction process. The significance of all other variables remained virtually unchanged.

geography are likely to be important because the productivity of agriculture is partly dependent on climatic and soil conditions which vary with distance from the equator. The degree of financial deepening of an economy will affect the productivity of investment through its role in allocating resources to the most productive sectors of an economy. Financial deepening is the case for financial liberalisation (Shaw, 1973). We measure financialization by the ratio of liquid liabilities to GDP (Levine, 1997). It is often claimed that government consumption distorts the allocation of resources and reduces the productivity of investment, so we include the ratio of government consumption expenditure to GDP as a potential regressor. Inflation can also distort the allocation of resources by diverting savings and investment into non-productive assets such as land, property and precious metals. The variability of inflation also affects the stability of an economy which, in turn, affects the utilisation of capital, so the rate of inflation and its standard deviation are included as independent variables. Finally, we control for population growth, and include the population size of countries to capture scale effects associated with market size. The initial level of per capita income is an additional regressor to test the convergence hypothesis.[5]

Econometric Methodology

Given the long list of potential regressors, a major empirical issue is to decide on the appropriate methodology to estimate the impact of the various variables. We employ Hendry's (1995) general-to-specific (Gets) model selection procedure, as embodied in the computer-automated Autometrics progamme of Doornik and Hendry (2013). Owen (2003) neatly describes the Gets methodology as 'the formulation of a "general" unrestricted model that is congruent with the data and the application of a "testing" down process, eliminating variables with coefficients that are not statistically significant, leading to a simpler "specific" congruent model that encompasses rival models' (p.609).

To iron out business cycle fluctuations in the per capita growth rate and investment ratio series, we use long-run cross section averages over the period 1980 to 2011. The use of long-run data also minimises potential endogeneity problems that may arise from short-run business cycle correlations between the two series. The same argument applies to other flow variables in the data set. All stock variables are measured as close as possible to the beginning of the period (1980) so that it is possible to estimate the impact on the net productivity of investment *after* the initial shock to an independent variable (which should take care of simultaneity problems). The Autometrics modelling procedure will select a well-specified, statistically robust and theory-consistent empirical model.

[5] Unfortunately, it was not possible to obtain information on R&D expenditure for our full sample of countries.

The econometric specification of the net productivity of capital (nPOI) model in equation (10) is:

$$nPOI = b_1 + a(I/Y)_i^{-1} + b\left(\frac{lnitialPCY}{I/Y}\right)_i + b_n\left(\frac{Zn}{I/Y}\right)_i + \left(\frac{\in}{I/Y}\right)_i \qquad i = 1 ---- 84 \qquad (11)$$

where Z_n is the vector of potential determinants of the productivity of investment discussed earlier , and *(ε)/(I/Y)* is the unobserved error term. The impact of investment is measured by the asymptote or constant (b_1) and the inverse of the investment ratio $(I/Y)_i^{-1}$ measures the returns to investment.

Table 3 reports the specific model chosen by Autometrics for the sample of 84 countries. The outlier detection test of Autometrics, based on the significance levels of the largest residuals, identifies two country dummies – Cote D'Ivoire and Rwanda. The regression model is well determined with a coefficient of determination (R^2) of 0.72, and ten explanatory variables are identified as significant at the one percent and five percent significance level. There is some evidence of heteroscedasticity, but the model remains well determined when heteroscedastic-consistent standard errors (HCSE) are used in column (ii). The diagnostic tests further show that the model is well-specified and that the residuals are normally distributed.[6] The explanatory variables in order of significance are: the standard deviation of inflation [INFLSDEV]; the growth of exports [GEX]; latitude [ABLAT]; government consumption [GCON]; political rights [PRIGHTS]; total years of education in 1980 [TOTED80]; total years of education interacted with the initial level of per capita income in 1980 [TOTED80xlnRDGP80]; trade openness [TOPEN], and the log of the initial level of per capita income [lnRGDP80]. The negative sign on the initial per capita income variable means that there is evidence of convergence of the net productivity of investment; this must be due to faster structural change in poor countries or catch-up. The asymptote implies an average productivity of investment across the 84 countries of 13 percent (compared with the estimate in equation (11a) in footnote 6 below of 14.5 percent). The coefficient on the inverse of the investment ratio (a) does not differ significantly from zero which means there is no evidence of diminishing returns to capital; in other words, no evidence that the productivity of investment declines as countries get richer. The Gets modelling procedure rejects the role of financial variables; population growth and size; the number of revolutions and coups, and the share of mining in GDP, in determining the productivity of investment.

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[6] In our more technical paper (Nell and Thirlwall, 2016), to overcome the presence of heteroscedasticity, we estimate equation (11) without dividing through by (I/Y) i.e. we estimate the equation:
$g\text{-}p = a + b_1(I/Y)_i + b(InitialPCY)_i + b_n(Z_n)_I + \varepsilon_i$ (11a). Since (11) and (11a) are mathematically equivalent we can derive the coefficients in equation (11) from the estimates of (11a). When this is done, there is very little difference in the estimates. The coefficient on the investment ratio is 0.145 and the intercept is not significantly different from zero.

Table 3:
Regression Results of the Investment Productivity Equation (11)[a]

Independent variable	(i) Specific Model	(ii) Specific Model (HCSE)[a]
$(I/Y)^{-1}$	0	0
Asymptote (b_1)	0.1306*** (5.26)	0.1306*** (4.87)
lnRGDP80/(*I*/*Y*)	–0.1539** (2.07)	–0.1539** (2.45)
TOTED80/(*I*/*Y*)	0.8155*** (2.70)	0.8155** (2.32)
(TOTED80 × lnRGDP80)/(*I*/*Y*)	–0.0834*** (2.68)	–0.0834** (2.39)
ABLAT/(*I*/*Y*)	0.0287*** (3.60)	0.0287*** (3.94)
GCON/(*I*/*Y*)	–0.0682*** (3.35)	–0.0682*** (2.80)
GEX/(*I*/*Y*)	0.1191*** (4.06)	0.1191** (2.40)
INFLSDEV/(*I*/*Y*)	–0.0004*** (4.75)	–0.0004*** (7.11)
PRIGHTS/(*I*/*Y*)	–0.1927*** (3.07)	–0.1927*** (2.72)
TOPEN/(*I*/*Y*)	0.0051*** (2.67)	0.0051*** (3.76)
Country dummy (Côte d'Ivoire)[b]	0.1108*** (2.91)	0.1108*** (7.94)
Country dummy (Rwanda)[b]	–0.1370*** (3.38)	–0.1370*** (7.96)
Diagnostic Tests[c]		
R^2	0.72	
Standard error ($\hat{\sigma}$)	0.035	
Reset (misspecification): F-test	{0.35}	
Normality test: χ^2 [2]	{0.85}	
Heteroscedasticity(S): F-test	{0.01}***	
Heteroscedasticity(X): F-test	{0.00}***	
Chow (43): F-test	{0.93}	
Chow (77): F-test	{0.70}	
Number of observations (*N*)	84 countries	

Notes:
a. The figures in parentheses (·) are absolute t-statistics and the figures in curly brackets {·} *p*-values. *** denotes significance at the 1% level and ** at the 5% level. The t-statistics in column (ii) are derived from heteroscedasticity-consistent standard errors (HCSE).
b. The significance levels of Côte d'Ivoire and Rwanda's scaled residuals are 0.97% and 1.63%, respectively, which fall below the one-tail 2.5% critical value of the outlier detection test. Thus, because the null of outliers (against the alternative of no outliers) cannot be rejected at the 2.5% significance level, two country dummies are automatically added to the regression model.
c. Two heteroscedasticity tests are reported: one that uses squares (S) and the other squares and cross-products (X). The null hypotheses of the diagnostic tests are the following: i) no functional form misspecification (using squares and cubes), ii) homoscedasticity, iii) the residuals are normally distributed, and iv) structural stability based on Chow tests. For more details, see Doornik and Hendry (2013).
Source: Nell and Thirlwall (2016).

Discussion of Results

Investment

Our finding of constant returns to capital means that changes in the investment ratio will have *permanent* growth effects on per capita income. This contrasts with the neoclassical interpretation of cross-country growth regressions (see Barro, 1991; Mankiw et. al., 1992) where a negative sign on the initial per capita variable is interpreted as diminishing returns to capital, so that permanent increases in the investment ratio only generate temporary growth effects. As we have already argued above, since the equation for the net productivity of investment (equation 11) provides a direct and unambiguous test of the returns to capital, the negative sign on the initial PCY in conventional 'new' growth theory estimating equations can no longer be interpreted as evidence of diminishing returns to capital. Recent panel data evidence in Bond et. al. (2010) supports the cross-country evidence presented here. They take a panel of 75 countries over the period 1960 to 2000 using annual pooled data with country-specific effects, and filtering out business cycle fluctuations. They report that ' a permanent increase in investment as a share of GDP from 9.1 percent (the first quartile of our sample distribution) to 15.1 percent (the sample median) is predicted to increase the annual growth of GDP per worker by about 2 percentage points' (p.1087). This implies a productivity of investment of 33 percent which is high. For individual countries, however, the mean estimate of the country coefficients shows a lower effect on growth with a productivity of investment of 16 percent which is close to our estimate of 13 percent in Table 3.

Education

With regard to education, the results in Table 3 show that the initial stock of education (TOTED80), as measured by the average years of primary, secondary and tertiary education, has a strong positive effect on the productivity of investment. The role of human capital stressed by 'new' growth theory is supported. A one year increase in education increases the productivity of investment by 0.82 percentage points. The interaction term of the initial level of education with the initial level of per capita income, which measures whether the ability of countries to absorb new technology (i.e. to catch-up) is related to education suggests that it is. The significant negative sign on [(TOTED80)x(lnRGDP80)] of -0.0843 means that the negative coefficient on the initial PCY variable increases from -0.1539 to -0.2382. In other words, an extra year of schooling enables a country with a backlog of technology to catch up at a slightly faster rate.

Trade

The results in Table 3 show that the two trade variables – the degree of openness (TOPEN) and the growth of exports (GEX) – are both statistically significant, but the impact of the growth of exports is greater. A ten percentage point increase in the growth of exports is associated with a 1.2 percentage point increase in the productivity of investment, whereas a ten percentage point increase in the level of openness only improves investment productivity by 0.05 percentage points.

The impact of export growth on the productivity of investment works from both the supply-side and the demand-side. Export growth allows a faster growth of imports which can improve the productivity of domestic capital. Export growth also has a direct effect on demand growth in an economy which helps keep capital fully employed. Even more important, export growth can lift a balance of payments constraint on domestic growth allowing all other components of demand to expand faster without causing shortages of foreign exchange (see Thirlwall, 2011 for an overview of the literature). The ability to maintain an economy at full employment, with demand growth matching potential supply growth, is vital for keeping the productivity of investment high.

Macroeconomic Variables

The two main macroeconomic variables found to be significant are the standard deviation of inflation (INFLSDEV) and the ratio of government expenditure to GDP (GCON), and they both impact negatively on the productivity of investment – although the impact is not large. A 10 percentage point increase in the standard deviation of inflation reduces the productivity of investment by only 0.004 percentage points. The main channel through which macro-instability can reduce the productivity of investment is through the difficulty that an unstable economy has in maintaining a full employment level of output. Stop and start policies of governments confronted with inflation, and other sources of instability, are not conducive to the full utilisation of capital capacity.

The channels through which a higher level of government consumption may reduce the productivity of investment are numerous, but the main effect is likely to be a diversion of resources away from the higher productivity of the private sector, and the debt implications of government borrowing to finance consumption. The impact, however, is not large. A 10 percentage point increase in GCON/INV reduces the productivity of investment by only 0.682 percentage points.

Geography and Institutions

The results in Table 3 show both geography and institutions matter for the productivity of investment. The positive impact on capital productivity of the absolute difference of a country from the equator (ABLAT) may have to do with the fact that tropical zones specialise more in agriculture than industry; that agricultural productivity itself is lower in the tropics than in the temperate zones, and temperate zones are less debilitating for workers than the heat of the tropics. The coefficient estimate of 0.0287 indicates that for a country ten degrees north or south of the equator, the net productivity of investment is nearly 0.3 percentage points higher.

With regard to political rights (PRIGHTS), the results in Table 3 indicate that a difference between 1 and 7 in the political rights index (with 1 high and 7 low) is associated with a difference in the productivity of investment of 1.16 percentage points. Democracy would appear to be good for growth.

Conclusion

The growth of an economy is equal by definition to how much it saves and invests as a proportion of national income, and the productivity of investment. Taking a cross-section of 84 rich and poor, developed and developing, countries over the period 1980-2011, we have shown that while investment is important for growth, differences in the productivity of investment are even more important in accounting for growth rate differences. To explore the causes of differences in the productivity of investment across countries, we convert a 'new' growth theory estimation equation into an investment productivity equation, and consider nineteen different variables that might explain productivity differences. Using the productivity of investment as the dependent variable also allows us to test the neoclassical growth hypothesis of diminishing returns to capital. The evidence across the 84 countries, using descriptive and econometric analysis, shows that the productivity of investment is as high in rich countries as it is in poor countries, although there are wide differences within groups of countries. The evidence supports the assumption of constant returns to capital so that investment matters for long-run growth, contrary to the prediction of orthodox neoclassical theory. The empirical evidence is consistent with the AK model of 'new' growth theory.

To explain the differences in the productivity of investment across countries we use a general-to-specific econometric model embedded in the software Autometrics which picks out the significant variables from all those that might be considered important. Of the nineteen variables considered, the most important seem to be related to macroeconomic-stability; education; export growth; geography and institutions. While these variables may not surprise, they do have important policy implications for countries which want to improve their growth performance. Indeed, these conclusions more or less mirror those of the World Bank's Commission on Growth and Development, headed by Michael Spence, which identified six major factors characterising the fastest growing economies in the world economy since 1950, namely: high saving and investment rates; fast export growth; macroeconomic stability; effective governance; import of knowledge and technology, and market-friendly policies (World Bank, 2008).

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Appendix 1: <u>List of Variables</u>

Dependent Variables:			
1) *g*	Growth rate of real GDP at domestic prices.	Average: 1980-2011.	WBDI.
2) $(g - p)$	Growth rate of real GDP per capita.	Average: 1980-2011.	WBDI.
3) nPOI	Net productivity of investment: $(g - p)/(I/Y)$	Average: 1980-2011.	WBDI.
Independent Variables (regressors):			
4) ABLAT (+)	Absolute latitude from the equator.	Measures the impact of geography on economic development. See Gallup et al. (1999).	See Sala-i-Martin (1997) for source.
5) FDEV90 (+)	Ratio of liquid liabilities to GDP. The ratio is a measure of financial development, as discussed in Levine (1997).	Following King and Levine (1993), we use an initial value. For most countries a value in 1990 is available. For those countries without a 1990 value, we chose the closest possible year in the interval 1991-1994.	The latest version of the dataset (November 2013) described in Beck et al. (2000).
6) GCON (-)	Ratio of general government consumption expenditure to GDP.	Average: 1980-2011.	WBDI.
7) GEX (+)	Growth rate of real exports of goods and services.	Average: 1980-2011.	WBDI.
8) GPO (*p*), (-) or (+)	Growth rate of population.	Average: 1980-2011. Scale effects (+) or resource depletion (-).	WBDI.
9) INFL (-) or (+)	Inflation rate derived from the GDP deflator.	Average: 1980-2011.	WBDI.
10) INFLSDEV (-)	Standard deviation of the inflation rate derived from the GDP deflator.	1980-2011.	WBDI.
11) INV (I/Y), (+)	Investment ratio = the ratio of gross fixed capital formation (I) to GDP (Y). Both I and Y are nominal domestic price values.	Average: 1980-2011.	WBDI.
12) lnPOP80 (+)	Natural logarithm (ln) of the population size in 1980.	Measures scale effects associated with market size. See Alesina et al. (2000).	WBDI.

<u>Note:</u> World Bank Development Indicators, 2012 (WBDI

Appendix 1: **List of Variables (Continued)**

Independent Variables:			
Variable (Expected Sign)	Description	Comments	Source
13) lnRGDP80 (-)	Natural logarithm (ln) of the initial level of purchasing-power-parity adjusted real GDP per capita income in 1980 (constant 2005 dollars).	The initial level for most of the countries is 1980. For the small number of countries without a 1980 value, the closest possible year.	WBDI.
14) MINING (+)	The share of mining and quarrying in GDP.	Data are for the year 1988 or the closest possible year.	Hall and Jones (1999).
15) OPEN (+)	Measures the proportion of years in the interval 1965-1990 in which an economy is open to international trade.	The binary index takes a value of 1 or 0, where 1 indicates open and 0 closed.	Sachs and Warner (1995).
16) REVCOUP (-)	Revolutions and Coups.	Number of military coups and revolutions	Barro (1991).
17) PRIGHTS (-)	A political rights index that measures democracy compiled by Gastil and his associates (1982-1983 and subsequent issues) from 1972 to 1994.	The index ranges from 1 to 7, with 1 indicating the group of countries with the highest level of political rights and 7 the lowest.	Barro (1998).
18) SECTER80 (+)	Average years of secondary and tertiary education of total population.	Initial value in 1980.	Barro and Lee (2013).
19) [SECTER80×lnRGDP80] (-)	Interactive (product) term, with variables defined above.	Initial values in 1980.	Barro and Lee (2013); WBDI.
20) TOTED80 (+)	Total education: average years of primary, secondary and tertiary education of total population.	Initial value in 1980.	Barro and Lee (2013).
21) [TOTED80×lnRGDP80] (-)	Interactive (product) term, with variables defined above.	Initial values in 1980.	Barro and Lee (2013); WBDI.
22) TOPEN (+)	The ratio of total trade (imports + exports) to GDP. Measures trade openness.	Average: 1980-2011	WBDI.

Note: World Bank Development Indicators, 2012 (WBDI, 2012).

APPENDIX 2: List of Countries

Number	Country	Income Classification (World Bank, 2013)
1	Argentina	Upper middle income
2	Australia	High income
3	Austria	High income
4	Bangladesh	Low income
5	Belgium	High income
6	Benin	Low income
7	Bolivia	Lower middle income
8	Botswana	Upper middle income
9	Brazil	Upper middle income
10	Cameroon	Lower middle income
11	Canada	High income
12	Chile	High income
13	Colombia	Upper middle income
14	Congo, Democratic Republic	Low income
15	Congo, Republic	Lower middle income
16	Costa Rica	Upper middle income
17	Cote d'Ivoire	Lower middle income
18	Cyprus	High income
19	Denmark	High income
20	Dominican Republic	Upper middle income
21	Ecuador	Upper middle income
22	Egypt	Lower middle income
23	El Salvador	Lower middle income
24	Finland	High income
25	France	High income
26	Gambia	Low income
27	Germany	High income
28	Ghana	Lower middle income
29	Greece	High income
30	Guatemala	Lower middle income
31	Honduras	Lower middle income
32	Hong Kong	High income
33	Iceland	High income
34	India	Lower middle income
35	Indonesia	Lower middle income
36	Israel	High income
37	Italy	High income
38	Japan	High income
39	Jordan	Upper middle income
40	Kenya	Low income
41	Korea	High income

42	Luxembourg	High income
43	Malawi	Low income
44	Malaysia	Upper middle income
45	Mali	Low income
46	Malta	High income
47	Mauritania	Lower middle income
48	Mauritius	Upper middle income
49	Mexico	Upper middle income
50	Morocco	Lower middle income
51	Mozambique	Low income
52	Netherlands	High income
53	New Zealand	High income
54	Nicaragua	Lower middle income
55	Norway	High income
56	Pakistan	Lower middle income
57	Panama	Upper middle income
58	Paraguay	Lower middle income
59	Peru	Upper middle income
60	Philippines	Lower middle income
61	Portugal	High income
62	Rwanda	Low income
63	Senegal	Lower middle income
64	Sierra Leone	Low income
65	Singapore	High income
66	South Africa	Upper middle income
67	Spain	High income
68	Sri Lanka	Lower middle income
69	Sudan	Lower middle income
70	Swaziland	Lower middle income
71	Sweden	High income
72	Switzerland	High income
73	Syria	Lower middle income
74	Tanzania	Low income
75	Thailand	Upper middle income
76	Togo	Low income
77	Trinidad & Tobago	High income
78	Tunisia	Upper middle income
79	Turkey	Upper middle income
80	Uganda	Low income
81	United Kingdom	High income
82	United States	High income
83	Uruguay	High income
84	Zambia	Lower middle income

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