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Why does the productivity of investment vary across countries?

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In his famous paper "An Essay in Dynamic Theory", Harrod (1939) expressed a country's actual growth rate (g) 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.

$$g = s/c \qquad (1)$$

where $s = S/Y$ and $c = \Delta K/\Delta Y = I/\Delta Y$. 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.

$$g = \frac{I}{Y} \cdot \frac{\Delta Y}{\Delta K} = \frac{I}{Y} \cdot \frac{\Delta Y}{I} \qquad (2)$$

where I/Y is the investment ratio and $\Delta Y/I$ 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. If 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: first of all, to show that there are large differences in the productivity of investment across countries; second, to econometrically test the possible causes of the

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differences in the productivity of investment, using explanatory variables that are commonly used in the literature on growth; and third, 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 evidence does not support the assumption of diminishing returns to capital. The productivity of investment is as high in rich countries as it is in poor countries, if not higher. We analyse a sample of 84 developed and developing countries over the 1980-2011 period. This is the largest sample of countries for which reliable data for a period exceeding thirty years are available. Nineteen potential determinants of productivity differences are considered using the "general-to-specific" model selection algorithm of Autometrics (Krolzig and Hendry, 2001; Doornik and Hendry, 2013).

The productivity of investment is an important but under-explored topic, with policy implications for countries that 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 productivity of investment and the role of investment in growth.

1. Orthodox growth theory: old and 'new'

Orthodox growth theory is still based on the neoclassical theory of growth first developed by Solow (1956) and Swan (1956). Neoclassical growth theory still dominates economics textbooks and the teaching of economic growth across the world. How the model achieved such widespread support is still something of a mystery, because most of its assumptions and predictions are evidently false.

The model is based on three basic assumptions, and has 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 that 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 employment or participation in the labour force, hours worked and migration; and we know that technical progress is endogenous, because investment responds to the pressure of demand that embodies technical change. New vintages of capital are more productive than older vintages. Harrod (1939) defined 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 (León-Ledesma and Thirlwall, 2000). There is now a large body of research showing that the natural rate of growth is endogenous, not exogenous, and responds to the actual growth rate (León-Ledesma and Thirlwall, 2000, 2002; Libanio, 2009; Vogel, 2009; Dray and Thirlwall, 2011; Lanzafame, 2014).

The second basic assumption of the neoclassical growth model is that all saving is invested; that there is no independent investment function. This assumption implies no long run deficiency of aggregate demand, ruling out long periods of secular stagnation during which growth is lower than its potential. It is a return to pre-Keynesian economics, which assumes that the rate of interest is the price that equilibrates the supply and demand for saving. Keynes showed this to be false; changes in income are what balances savings and investment via the multiplier, and the rate of interest is the price that 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 1, 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 1, so the productivity of investment is assumed to fall as the capital-labour ratio rises, i.e. diminishing returns to capital.

These assumptions lead to the model's three basic predictions. The first is that, 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). The second is that, 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 productivity of investment 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. The latter is determined by the growth of the labour force and labour productivity. The model begs the question: how long is the long run? Early theoretical simulation models (e.g. Sato, 1966; Atkinson, 1969) suggested a transition of anything between 50 and 80 years, which brings to mind the quip of Keynes (1923) that in the long run we are all dead. It is in the present that we live and act, and current investment will matter for growth performance. How important investment is for growth is an empirical question that we will 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; therefore there should be a convergence of per capita incomes across the world. Historically, (see Bourguignon, 2015; Milanovic, 2016) we have not observed the convergence of living standards across countries as measured by the international Gini ratio, which uses the average level of per capita income of each country to make the calculation. 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 saving 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, meaning that the productivity of investment is not higher in poor countries than in rich countries? This is a matter that we will explore later.

The lack of convergence of per capita incomes across the world gave rise in the 1980s to what has become known as the 'new growth theory' or endogenous growth theory. 'New' models of economic growth, but building on the orthodox supply-oriented theory, were pioneered by Romer (1986) and Lucas (1988), and 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) that keep the productivity of investment 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:

$$\frac{K}{Y} = \frac{K}{L} \cdot \frac{L}{Y} \tag{3}$$

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 at the same rate 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.

$$Y = AK \tag{4}$$

where Y is output, K is capital (broadly defined) and A is a constant. On first 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 $c = 1/A$ is the actual incremental capital-output ratio.

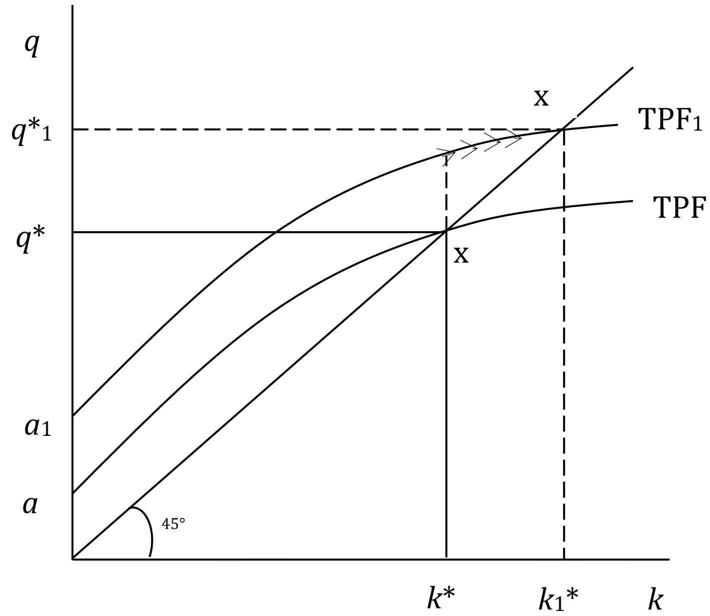
As a matter of historical interest, the 'new' growth theorists were not the first to explain why the productivity of investment may not decline as countries get richer and accumulate more capital per head. Many years prior, Nicholas Kaldor, the famous Hungarian/Cambridge economist (and bête noire of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

> "[a]s 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 […]; 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" (*ibid*., p. 178).

Kaldor's explanation was based on his innovation of the technical progress function (TPF), which was designed to replace the neoclassical production function with its artificial distinction between movements along the function and shifts in the function. The TFP relates the growth of output per man (q) 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:

On the vertical axis, q measures the growth of output per worker; and on the horizontal axis, k measures the growth of capital per worker. 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 curve measures

Figure 1 – *Kaldor's technical progress function*



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 point *x*, (q^*, k^*), the economy is in equilibrium. Now suppose there is an upward shift of the TPF curve 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 q_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. This anticipates precisely the ‘new’ endogenous growth theory.

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 ($q_1^* > q^*$). To quote Kaldor again (1972):

> “[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” (*ibid*., pp. 11-12).

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

2. Investment and growth, and ‘new’ growth theory

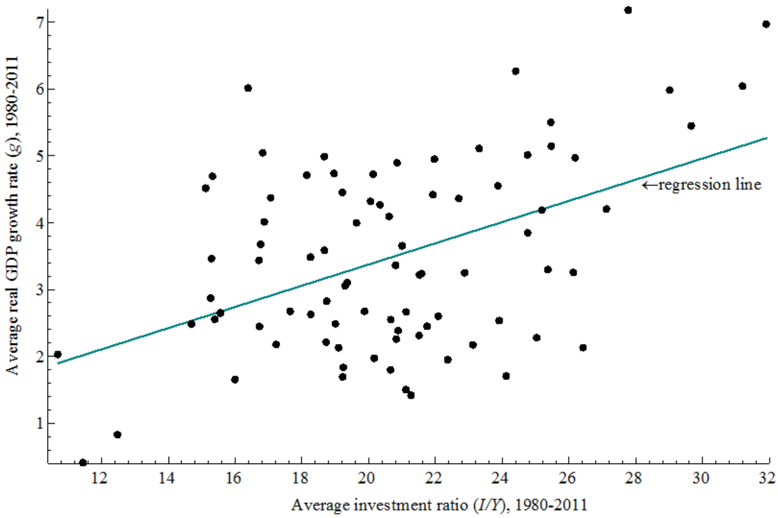
Now let us look at the evidence on the relationship between investment and economic growth. We take 84 rich and poor countries for which reliable data are available over the years 1980 to 2011, and plot the scatter diagram in figure 2.

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 that is confirmed by the estimation of a simple cross-section regression equation, which gives (t values in parentheses):

$$g = 0.20 + 0.16\,(I/Y) \qquad (6)$$

$$(0.28) \quad (4.79)$$

Figure 2 – *Investment and growth*



Note: figure 2 is scaled according to the lowest investment ratio in the sample, which is 10.7%. *Source*: *World Bank Development Indicators*, see appendix (World Bank, 2012).

The regression coefficient of 0.16 is statistically significant at the 99% confidence level, and implies an average productivity of investment across the sample of 16%. However, the coefficient of determination (R^2) 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 population growth (p) into account and regressing the rate of growth of per capita income on the investment ratio gives:

$$g - p = -2.64 + 0.21\,(I/Y) \qquad (7)$$

$$(-4.73) \quad (7.94)$$

Now the R^2 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):

$$g - p = a + b \ln(iPCY) \quad (8)$$

where $g - p$ is the average growth of per capita income (PCY) over a period and $\ln(iPCY)$ 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 researchers add other explanatory variables to test for *conditional* convergence to see whether the sign on the $\ln(iPCY)$ becomes 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 in support of 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" (*ibid.*, p. 409). Barro and other 'new' growth theorists are really neoclassical economists in disguise. Theirs are still supply-oriented models, in which demand plays no part. The only difference with 'old' growth theory is that each country reaches its own steady-state level of per capita income, 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,

p. 946) perceptively remark: "[i]f 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, through differences in the productivity of investment.

Let us consider in more detail an augmented 'new' growth theory-estimating equation:

$$g - p = a + b \ln(iPCY) + b_1(I/Y) + b_n(Z_n) \qquad (9)$$

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 $\Delta Y/I$, i.e. the productivity of investment. But in new growth theory, the productivity of investment is never treated as a dependent variable. Moreover, and most importantly, 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 both with faster structural change from low to higher productivity sectors in poor countries, and 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" (*ibid*., p. 160).

3. Measuring the productivity of investment

These weaknesses in the new growth theory empirical literature, and the interpretation of its 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:

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

There are many other ways of measuring the productivity of investment, but this is by far the simplest and the most consistent way for cross-country analysis.[1] The variable on the left hand side of equation (10) is what we call the adjusted or net productivity of investment (which adjusts for the contribution that population growth makes to output growth through the growth of the workforce).[2] 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, whereas 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.[3] 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) did, as a rehabilitation of the neoclassical model with diminishing returns to capital, because this has already been controlled for.

4. Descriptive analysis

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

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

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

[3] In Nell and Thirlwall (2017), we show more formally that the diminishing returns to capital hypothesis derived from the empirical model in equation (10) is consistent with Solow's (1956) neoclassical model, while the constant returns hypothesis is compatible with the theoretical framework of AK-style endogenous growth models.

countries, which includes nineteen explanatory variables over the period 1980-2011. The precise definition of the variables, and the countries taken, are given in appendix, tables A1 and A2. Before making an econometric estimation, however, it is informative to look at the raw data on gross investment productivity and net investment productivity (that is, adjusted for population growth) 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, along 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	*POI* (%)	($g - p$) (%)	*net POI* (%)	I/Y (%)
LI	21.35	0.86	4.10	16.93
(13 countries)	(7.92)	(1.44)	(9.58)	(3.46)
LMI	18.52	1.35	6.47	19.94
(23 countries)	(6.32)	(1.49)	(7.50)	(4.23)
UMI	18.32	2.17	9.45	22.13
(17 countries)	(4.14)	(1.26)	(4.45)	(3.93)
HI	13.10	2.07	8.91	22.16
(31 countries)	(4.90)	(0.97)	(3.40)	(3.58)

Note: standard deviations in parentheses.

Table 2 – *Income quartiles: initial per capita income levels, 1980*

Income Classification	*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%, whereas it is nearly 9% in the high-income countries. But note that the standard deviation in the low- and middle-income countries is much larger than in the upper middle-income and high-income countries. Table 2 tells a similar story, except now the net productivity of investment is more similar across low and high-income countries. The richest quartile of countries has a productivity of 7.7%, and the poorest quartile has a productivity of 6.5%, but again the standard deviation in the poorest two quartiles is large relative to the richest two quartiles. Overall, this means that there is a large cross-section variation among the poorest countries, as well as across all countries.

If we further divide our sample of 84 countries into equal halves according to the 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% for rich countries and 6.5%

for poor countries, with standard deviations of 3.5% and 8.2% in each half, respectively.

Overall, 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 to explain with our econometric modelling. We can say in advance that there are a number of significant factors 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.

5. Determinants of the productivity of investment

Many factors determine a country's productivity of investment. We consider nineteen potential explanatory variables that we think might be important, and which have been used in the new growth theory literature as independent variables. A full list of regressors and their definition is given in appendix, table A1.

The education and skill of the workforce is likely to play an important role, so we include the average years of schooling at the primary, secondary and tertiary level, and also interact education with the initial level of per capita income to test whether education helps a country 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 in exports will affect the capacity utilisation of capital because a shortage of foreign exchange can push an economy into recession. We include a trade openness variable and the

[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.

growth of exports as regressors. The structure of an economy will matter, and we measure it by the share of mining and quarrying in GDP. Latitude and geography are likely to be important because the productivity of agriculture is partly dependent on climatic and soil conditions which vary on the basis of the distance of a country 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 financial deepening by the ratio of liquid liabilities to GDP (Levine, 1997).

A frequent claim is 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]

6. 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-

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

automated Autometrics programme (Doornik and Hendry, 2013).[6] 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” (ibid., 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 from 1980 to 2011. The use of long-run data also minimises potential endogeneity problems that might 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.

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

$$nPOI_i = b_1 + a\left({}^{I}/_{Y}\right)_i^{-1} + b\left[\frac{ln(iPCY)}{(I/Y)}\right]_i + b_n\left(\frac{Zn}{I/Y}\right)_i + \left[\frac{\varepsilon}{(I/Y)}\right]_i \quad i = 1, \ldots, 84 \quad (11)$$

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

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[6] The advantages of the Gets methodology compared to other approaches, such as extreme bounds analysis (see Leamer, 1983; 1985) and Bayesian Model Averaging (see Fernández *et al.*, 2001), are discussed in Hendry and Krolzig (2004) and Hoover and Perez (2004).

Table 3 reports the specific model chosen by Autometrics for the sample of 84 countries.7 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 (R2) of 0.72, and ten explanatory variables are identified as significant at the 1% and 5% 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.8 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 [TOTED80 × ln(RDGP80)]; trade openness (TOPEN), and the log of the initial level of per capita income [ln(RGDP80)].

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 to catch-up. The asymptote implies an average productivity of investment across the 84 countries of 13% (compared with the estimate in equation (11a) of 14.5% in footnote 8). The coefficient on the inverse of the investment ratio (a) does not differ significantly from zero, which means there is no evidence of

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7 For details on the settings we use in Autometrics to obtain the specific model, see appendix B in Nell and Thirlwall (2017).

8 In our more technical paper (Nell and Thirlwall, 2017), to overcome the presence of heteroscedasticity, we estimate equation (11) without dividing by (I/Y) ; i.e. we estimate the equation:

$$(g - p)_i = a + b_1(I/Y)_i + b[\ln(iPCY)]_i + b_n(Z_n)_i + \varepsilon_i \qquad (11a)$$

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.

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 the determination of the productivity of investment.

Table 3 – *Regression results of the investment productivity equation*

	(*i*) Specific model	(*ii*) Specific model (HCSE)
$(I/Y)^{-1}$	0	0
Asymptote (b_1)	0.1306*** (5.26)	0.1306*** (4.87)
ln(RGDP80)/(*I*/*Y*)	−0.1539** (2.07)	−0.1539** (2.45)
TOTED80/(*I*/*Y*)	0.8155*** (2.70)	0.8155** (2.32)
[TOTED80 × ln(RGDP80)]/(*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)	0.1108*** (2.91)	0.1108*** (7.94)
Country dummy (Rwanda)	−0.1370*** (3.38)	−0.1370*** (7.96)

Diagnostic Tests	
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*)	countries

*** denotes significance at the 1% level and ** at the 5% level.

Note: the figures in parentheses are absolute *t*-statistics and the figures in curly brackets *p*-values. The *t*-statistics in column (*ii*) are derived from heteroscedasticity-consistent standard errors (HCSE). 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. 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 (2017).

7. Discussion of results

7.1. Investment

Our finding of constant returns to capital means that changes in the investment ratio will have *permanent* growth effects on per capita income growth. This is in contrast with the neoclassical interpretation of cross-country growth regressions (see Barro, 1991; Mankiw *et al*., 1992), according to which 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 from 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% (the first quartile of our sample distribution) to 15.1% (the sample median) is predicted to increase the annual growth of GDP per worker by about 2 percentage points" (*ibid*., p. 1087). This implies a high productivity of investment of 33%. For individual countries, however, the mean estimate of the country coefficients shows a lower effect on growth, with a productivity of investment of 16%, which is close to our estimate of 13% in table 3.

7.2. 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. An increase in education by one year 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 case. The significant negative sign on [TOTED80 × ln(RGDP80)] 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 faster rate.

7.3. 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 10 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 investment. Export growth also has a direct effect on demand growth in an economy which helps to 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.

7.4. Macroeconomic variables

The two main macroeconomic variables found to be significant are the standard deviation of inflation (INFLSDEV) and the ratio of government consumption expenditure to GDP (GCON), and they both have negative impacts 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 carried out by governments confronted with inflation, as well as 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 result does not imply, of course, that fiscal policy is ineffective, and, in any case, its impact is weak. A 10-percentage points increase in GCON/INV reduces the productivity of investment by only 0.682 percentage points.[9] We have not considered the impact of government investment on the overall productivity of investment.

7.5. Geography and institutions

The results in table 3 show that both geography and institutions matter for the productivity of investment. The positive impact of the absolute distance of a country from the equator (ABLAT) on the productivity of investment 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 that 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.

Regarding political rights (PRIGHTS), the results in table 3 indicate that a difference between 1 and 7 in the political rights index (with 1 signifying a high level and 7 a low level of political rights) is associated with a difference in the productivity of investment of 1.16 percentage points. Democracy would appear to be good for growth.[10]

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[9] Nell and Thirlwall (2017) argue that the small magnitude of the coefficient is due to the growth-promoting effect of some components of government consumption spending and the growth-reducing effect of others.

[10] The political rights index is measured until the early 1990s and per capita income growth is averaged over the period 1980-2011. Thus, to a large extent, the results are

8. Conclusion

The growth of an economy is equal by definition to the product of 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 the differences in the productivity of investment across countries, we convert a new growth theory-estimating equation into an investment productivity-estimating 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 descriptive evidence across the 84 countries shows that the productivity of investment is as high in rich countries as it is in poor countries, while the econometric analysis finds no significant relation between investment and its productivity. Overall, the evidence supports the assumption of constant returns to capital, meaning 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 the others 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 be surprising, they have important policy

capturing the growth effect *after* an initial shock to the political rights index. In addition, since geography appears to have played an important role in determining the quality of institutions (Acemoglu *et al*., 2001; Rodrik *et al*., 2004), the significance of the physical geography variable (absolute latitude) in table 3 may also control for any endogeneity bias.

implications for countries that 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

Table 1A – *List of variables*

Variable (expected sign)		Description	Construction	Source
1)	*g*	Growth rate of real GDP at domestic prices	Average: 1980-2011	*World Bank Development Indicators 2012* (WBDI, 2012)
2)	$(g - p)$	Growth rate of real GDP per capita	Average: 1980-2011	WBDI (2012)
3)	*nPOI*	Net productivity of investment: $(g - p)/(I/Y)$	Average: 1980-2011	WBDI (2012)
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 (2012)
7)	GEX (+)	Growth rate of real exports of goods and services	Average: 1980-2011	WBDI (2012)
8) (+)	GPO (*p*), (–) or	Growth rate of population. Denotes scale effects (+) or resource depletion (–)	Average: 1980-2011	WBDI (2012)

(*continued*)

(*continues*)

Variable (expected sign)		Description	Construction	Source
9)	INFL (–) or (+)	Inflation rate derived from the GDP deflator	Average: 1980-2011	WBDI (2012)
10)	INFLSDEV (–)	Standard deviation of the inflation rate derived from the GDP deflator	Value 1980-2011	WBDI (2012)
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 (2012)
12)	ln(POP80) (+)	Measures scale effects associated with market size. See Alesina *et al.* (2000)	Natural logarithm (ln) of the population size in 1980	WBDI (2012)
13)	ln(RGDP80) (–)	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 (2012)
14)	MINING (+)	The share of mining and quarrying in the 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 *et al.* (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 (1981) 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)

(*continued*)

(*continues*)

Variable (expected sign)		Description	Construction	Source
18)	SECTER80 (+)	Average years of secondary and tertiary education of the total population	Initial value in 1980	Barro and Lee (2013)
19)	[SECTER80 × ln(RGDP80)] (–)	Interactive (product) term, with variables defined above	Initial values in 1980	Barro and Lee (2013); WBDI (2012)
20)	TOTED80 (+)	Total education: average years of primary, secondary and tertiary education of the total population	Initial value in 1980	Barro and Lee (2013)
21)	[TOTED80 × ln(RGDP80)] (–)	Interactive (product) term, with variables defined above	Initial values in 1980	Barro and Lee (2013); WBDI (2012)
22)	TOPEN (+)	The ratio of total trade (imports + exports) to GDP. Measures trade openness	Average: 1980-2011	WBDI (2012)

Table A2 – *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

(*continued*)

(*continues*)

Number	*Country*	*Income classification (World Bank, 2013)*
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

(*continued*)

(*continues*)

Number	**Country**	**Income classification (World Bank, 2013)**
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