The NTV Model for Total Factor Productivity

Andrew Smithers

Key Points

- The consensus model for total factor productivity is unsatisfactory; the alternative, non-technology variables ('NTV') model resolves the objections to it and should therefore be preferred by economists.
- The key objections to the consensus model are that it is untestable, its assumption about corporate behaviour is falsified when tested and, for the accounting framework to function, the labour/capital ratio has to be as flexible on old capital as it is on new: an assumption which seems most unlikely.
- The differences in the results are non-trivial and the NTV model has positive implications for economic policy by showing how they could be changed to boost growth.
- NTV comprises all the variables, other than changes in labour and technology, that determine the level of investment and the capital stock. Changes in NTV are the net impact on the incentive to invest resulting from changes in the individual constituents, which are profit margins, the cost of equity, the cost of debt, leverage, corporation tax and the hurdle rate, which is the minimum expected return on equity needed to make new investment worthwhile in the opinion of management.
- The consensus model assumes that investment is partly determined by changes in the cost of capital while ignoring the impact of changes in the cost of equity and debt and in leverage. I show that this assumption is unjustified and why it is preferable to use NTV.

Introduction

This paper revises and extends my previous one on total factor productivity (TFP),[1] in which I proposed that the non-technology variables (NTV) model should be preferred to those that follow the current consensus approach. I include in this paper the equations for calculating TFP by two different approaches based on completely independent data and show that these can be used to test the validity of the model.

Both the NTV and the consensus models seek to determine the contribution to total growth made by changes in technology. The growth rate determined by changing technology is termed TFP, with the balance coming from growth in the labour supply and the volume of the capital stock. Both models assume that the rate of change in the capital stock depends on the level of investment net of capital consumption.

The differences between the two models include the definition of capital consumption and assumptions about corporate and investor behaviour. The results of the models differ significantly and have important consequences for economic policy. In setting out these differences I explain my reasons for preferring those used in the NTV model.

Defining the Capital Stock

The capital employed in the economy comprises natural endowments including land, fixed produced capital (equipment and buildings) and inventories. In both models it is assumed that the volume of land is fixed and that inventories can for the most part be ignored. The models therefore seek only to measure fixed produced capital.

The NTV model defines the volume of the capital stock as the 'gross capital stock', which is the amount of past investment that is still in use, measured at its original cost adjusted to current prices. Its calculation is based on survey data provided in the USA by the Bureau of Economic Analysis (BEA). The Organisation for Economic Co-operation and Development's (OECD) manual claims that this definition is '…based on the assumption

[1] Building a testable model to estimate total factor productivity. *World Economics* **18**, 2, April–June 2017.

that an asset's production capacity remains fully intact until the end of its service life'.[2] It is important to note that this is not correct. No such assumption is made.

The consensus objection to the use of the gross capital stock as the definition of its volume would be valid only if the objector could show that it is inconsistent with other assumptions in the model. Provided the assumptions are consistent the only valid objections would not be about the definitions used but only whether the resulting model is either untestable or that if fails when tested. The consensus objection to a model that defines the volume of capital as the gross capital stock would be valid if it also assumed that the past productivity of the existing capital stock is unchanged until scrapped. The NTV model does not do this and there is therefore no valid objection to its use of the gross capital stock to define volume.

Changes in the capital stock arise from new investment and changes in the volume and value of the existing stock, which in turn are affected by capital consumption, maintenance, depreciation and scrapping. These are four different concepts which are often confused, partly because they are seldom carefully defined, but also because corporate accounting definitions are often different from those used by economists. I will therefore seek to use these terms precisely, both for an ideal world in which all the necessary data are readily amenable to measurement and for the real one.

Equipment does not decay if properly maintained but it will do so if not. Houses and old cars for example last indefinitely if fully serviced and will continue to produce the same output as before. Maintenance is therefore the cost of sustaining the output per person from a given piece of capital equipment. This, however, is not the way in which maintenance costs are actually recorded. While fully maintained equipment is capable of producing its output for ever, it will not be fully maintained unless doing so is worthwhile. The recorded charge for maintenance is the amount actually spent. Once constructed, equipment has embedded in it the technology of its time. Its productivity depends on its vintage. Even ignoring cyclical fluctuations, equipment is not always employed at its maximum potential

[2] *The OECD Productivity Manual. A Guide to the Measurement of Industry-level and Aggregate Productivity* by Paul Schreyer, No. 2, Spring 2001.

when initially installed. Output may be subsequently enhanced by improvements in the education of the workforce or from the experience of using the equipment. Subject to an important proviso, the output per person employed is stable and the value of the output will fall steadily as real wages rise.[3] The fall in value arising from rising real wages is depreciation. If the labour share of output is stable and there are no changes in the value placed on a given stream of profits, the rate of depreciation will be determined by the rise in labour productivity. In practice depreciation is calculated from changes in the value of equipment, shown by surveys, for which the rise in wages is not the only cause. The rate of depreciation does not fluctuate from year to year with the changes in value, but is derived from the underlying trend.

The consensus model seeks to define the volume of the capital stock as 'capital services', which 'are a flow which in nominal terms equals profits or, in national income accounting items gross operating surplus'.[4] Calculating the volume of the capital stock from data on capital services thus involves assessing their contribution to output and valuing this at some assumed cost of capital. Different approaches to these two issues have resulted in the criticism that 'fairly innocuous differences in assumptions can lead to very different estimates of TFP growth'.[5]

The consensus growth accounting framework does not provide a suitable means of determining the contribution of investment to economic growth if, as seems clearly the case, the technology of its time is embedded in investment as it takes place. Technical progress and investment are therefore intertwined in a way for which consensus growth accounting fails to account. Among the very stringent assumptions needed for the growth accounting framework to function the labour/capital ratio has to be as flexible on old

[3] R.M. Solow, J. Tobin, C.C. von Weizsacker and M. Yaari, Neoclassical growth with fixed factor proportions. *The Review of Economic Studies* **33**, 2, April 1966.

[4] Capital stocks and capital services: Integrated and consistent estimates for the United Kingdom 1950–2013 by Nicholas Oulton and Gavin Wallis published by *Elsevier Economic Modelling* 54 (2016).

[5] *Measuring Growth in Total Factor Productivity* by Swati R. Ghosh and Aart Kraay, published by the World Bank PREM notes No. 42 September, 2000.

capital as it is on new and, as Martin Weale points out, this seems most unlikely to be true.[6]

Changes in the Volume and Financing of the Capital Stock

A coherent model for the volume of the capital stock will explain how it changes through additions from new investment and declines through capital consumption. In the NTV model the volume of the capital stock is the amount of unscrapped equipment measured at its original cost at current prices. In the consensus model it is measured through changes in the value placed on the output of capital services. Both models assume that the additions are determined by the amount of current technology in which it is worthwhile to invest. The level that is 'worthwhile' in the consensus model is that at which the return is at least equal to the cost of capital. New investment reflects its current cost and is thus free from the valuation problems associated with the existing capital stock. The measures of return and cost of capital depend, however, on the definition of profit. In the NTV model what is 'worthwhile' is determined by the non-technology variables that are identified as having an effect on investment decisions.

Corporate capital comes in two forms, equity and debt, and its cost depends on their individual cost, leverage—which measures the proportions of each involved, the rate of corporation tax and the rules of tax deductibility. Leverage, interest and corporation tax rates are known and thus the cost of capital can be calculated if the cost of equity is known. I showed in my previous paper that the cost of equity in the USA is known over the long term because the real return on equity is mean-reverting around 6.4%,[7] and over the short term because the current degree of over- or under-valuation of the market is known. At any one time therefore the real cost of equity, after corporation tax, is the long-term return adjusted for the current degree of misvaluation. We can therefore calculate the current cost of corporate capital

[6] Foreword to *Productivity and the Bonus Culture* by Andrew Smithers to be published by OUP forthcoming July 2019.
[7] Smithers (2017).

and it is clear that companies have not varied their level of investment in response to changes in its cost.

The NTV model accepts this and notes that, as the long-term return on equity is mean-reverting, corporations consider it worthwhile to invest if the expected return on the equity component needed for its finance is at least equal to the 'hurdle rate', which varies around 6.4%.

Those using the consensus model typically define the cost of capital from returns as the ratio of operating profits, measured before interest and corporation tax, to their chosen estimate of the capital stock. Operating profits may also be measured before capital consumption and in theory allowance can be made for corporation tax. The variety of results from those using this model naturally follows from the use of varying definitions for both the capital stock and profits. I have not encountered any, however, which seek in practice to allow for corporation tax and neither in theory nor practice does the consensus model appear to allow for leverage and the different costs of debt and equity.

It is reasonable to ignore the effect of leverage if it has no impact on the cost of capital as defined and this definition of cost is that used by companies when deciding on their levels of investment. The first condition is satisfied if the cost is defined as the returns before interest and corporation tax. The second one is based on the assumptions used in the Miller-Modigliani theorem and which, while aprioristically reasonable, are inconsistent with the way that companies behave. The Miller-Modigliani theorem holds that, subject to certain conditions, the 'value' of a firm is not affected by its capital structure. For leverage to be irrelevant to investment decisions not only do these conditions have to be met but companies' investment decisions must depend on their managements seeking to maximise corporate 'value', which they demonstrably do not.

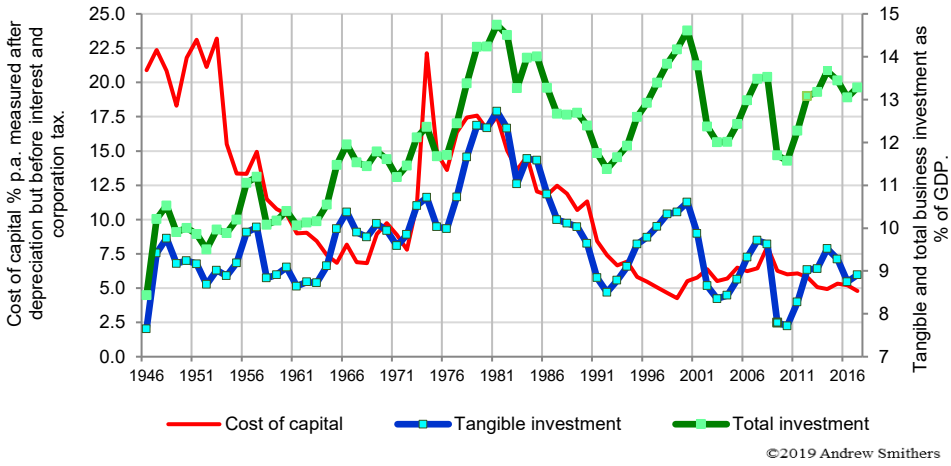
Table 1: Correlations between business's fixed investment as % of GDP and the cost of capital

	Tangible investment	Total investment including intangibles
	Coefficients of correlation	
1946 to 2017	0.283	–0.375
1946 to 1981	0.074	–0.081
1981 to 2017	0.729	0.285
	R^2	
1946 to 2017	0.080	0.140
1946 to 1981	0.005	0.007
1981 to 2017	0.531	0.0813

Sources: National Income and Product Accounts (NIPA) Tables 1.1.5 and 1.14, and Z1 Table B.103.

Table 1 shows that there is no significant correlation between the cost of capital and either tangible investment or total investment when measured over the whole period; nor if the period is divided into two sub-periods is there any significant correlation between the cost of capital and total investment. There is, however, a significant correlation between the cost of capital and tangible investment from 1981 to 2017, but it is perverse as investment and the cost of capital both fell over this period.

Figure 1: Business investment and the cost of capital measured before interest and corporation tax



Sources: NIPA Tables 1.1.5 and 1.14 and Z1, Table B.103.

Figure 1 compares the cost of capital, measured before interest and corporation tax but after depreciation, with business investment both tangible and total as a percentage of GDP.[8] The total cost of capital depends on the varying proportions of equity and debt and their cost, with the estimate of the cost of equity being derived from the level of over- and under-valuation of equities shown by the *q* ratio compared with the long-term return on equity to shareholders of 6.4%.

There appears to be no relationship between the cost of capital and the level of investment. As equity is the dominant element in the cost of capital, this fits with the evidence that corporations are indifferent to the cost of equity, as shown in my previous paper.[9]

In the Miller-Modigliani theorem 'value' is a company's net worth not its current market value. If companies were concerned with the former they would issue new shares or reduce dividends when the cost of equity was

[8] The correlation coefficients are virtually identical whether output is measured by Gross Domestic Product or Net Domestic Product.
[9] See Figure 6 of Smithers (2017).

below the long-term return. But shareholders are concerned with the stock market value rather than net worth and, as new issues tend to depress share prices, in the interests of self-preservation managements habitually favour buy-backs rather than new issues, even when the stock market sells, as it does today, well above the real net worth of its constituent companies.

Shareholders' concern is with the companies' stock market value rather than their net worth, so the cost of capital cannot be assumed to be independent of leverage, as it would if the Miller-Modigliani theorem held in practice. Growth models which seek to allow for corporation tax but not for leverage are therefore invalid.[10]

By preferring the market price to net worth investors can be accused of myopia, as over the long term the latter determines the former. It should, however, be noted that this does not indicate that investors are irrational. Shareholders are not homogeneous; those saving for their retirement have longer time horizons than pensioners and investors are not irrational to prefer share prices to underlying value if they believe share prices are unlikely to fall in the shorter term or that they are unable to time, with sufficient accuracy to improve their returns, when to leave and when to return to the stock market. It would be irrational if the correct timing of the market could be forecast, but it is unlikely that markets then would ever be misvalued. Fund managers whose sales vary with their recent performance will be rationally myopic and the rise in their importance is likely to have increased investor dislike of new share issues. In the NTV model, the volume of the capital stock increases with additions through new investment and declines through scrapping. Investment occurs when the expected return on the equity needed to finance it exceeds the hurdle rate, for which we have data since 1801, and which appears to be mean-reverting around 6.4%.[11] In addition to fixed produced capital, companies need to own or lease land and to finance their trade credit and inventories. Usually these assets can readily be sold and fruitfully employed to finance other activities. It will therefore be sensible for companies to scrap equipment when the returns from using

[10] As, for example, the Hall-Jorgensen model of investment (20 November 2017).
[11] See Figure 4 of Smithers (2017).

it reduce the value of their output below the combined value of the other assets needed for production and any scrap value of the equipment.

Measuring TFP in the NTV Model

Volume is measured by the gross capital stock, which in the USA is calculated by the BEA from surveys. Unfortunately they do not publish the resulting data but they do provide the average life of the existing stock at current prices since 1925 (BEA Fixed Asset Table 1.9). This can be combined with the data on investment on private sector tangible produced fixed assets (BEA Fixed Asset Table 1.5) to produce data at current prices since 1901. Using the GDP deflator of fixed investment since 1929 and earlier Bureau of Labor Statistics (BLS) data on consumer prices I have converted these to constant prices. I have extended this to 1870 by linking the series with data from Òscar Jordà, Moritz Schularik and Alan Taylor (2016). Making only the assumption that old equipment is scrapped before new, I have constructed a series from 1952 to 2017 for the gross capital stock.[12]

Growth in output is the change in employment multiplied by labour productivity, measured here as net domestic product (NDP) per person employed. If the capital stock is unchanged, labour productivity can rise through changes in TFP. It can also rise without any change in technology if more investment becomes worthwhile. There are a number of non-technology variables (NTV) changes in which will stimulate or depress such investment while technology remains unchanged. If all change is due to TFP then the capital stock will rise in line with employment. If, however, there is a difference in the rates of change of employment and the capital stock the difference will be the contribution from this additional capital volume. To measure this contribution I deduct the growth of the employment from that of the capital stock and the resulting contribution to the growth of output is this difference divided by the capital/output ratio for the period. The capital stock can grow at a different pace from employment only if NTV change.

[12] When I wrote my previous paper (Smothers, 2017) I was not aware of the data series from Òscar Jordà, Moritz Schularik and Alan Taylor. I use it in this paper because it provides greater continuity over time than the data that I employed before and the series should be more reliable. One result is that the data for the gross capital stock covers a shorter period than the set used before.

With unchanged labour any improvement in growth is an improvement in labour productivity, but this can arise from either TFP or a change in NTV. If it's the former then output grows without any addition to the volume capital/labour ratio (Hicks neutral) and when output grows through changes in NTV there is a rise in the volume capital/labour ratio (Harrod neutral).

The capital stock is determined by the interaction of the level of NTV with the current level of technology: when NTV moves so as to allow the finance of more investment without any improvement in technology then $(\Delta K/K - \Delta L/L) > 0$. Thus improvements in technology will improve output without any increase in the volume of capital. Any difference in the growth rate of the volume of capital and the volume of labour will depend on changes in NTV that allow more capital to be financed without a change in technology. Changes in NTV can therefore be measured from the different growth rates of the volumes of capital and labour.

$$\text{So } \Delta NTV = (\Delta K/K - \Delta L/L) \quad (1)$$

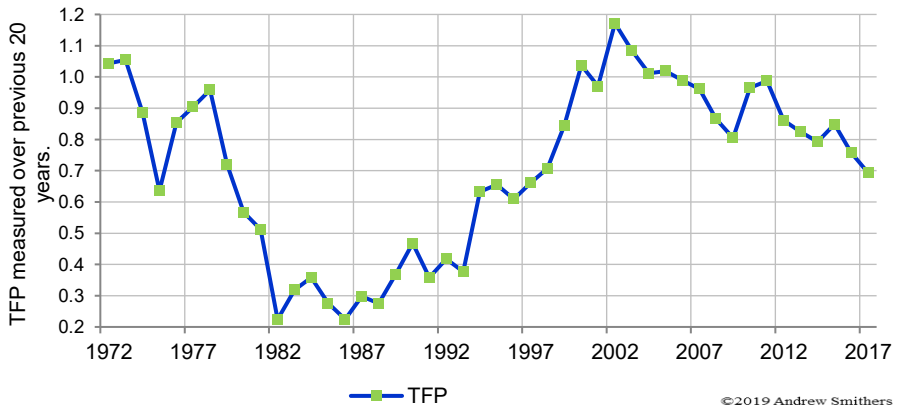
Equation 1 shows that the change in NTV is equal to the change in volume capital/labour ratio. The contribution of changes in the gross capital stock to output growth is $(\Delta K/K - \Delta L/L)/(K/Y)$ and, after deducting this and the growth of employment from total growth in output, the balance measures TFP.

The gross capital stock can be measured to include or exclude intangible investment. As explained in my 2017 paper I prefer to exclude intangibles because their purpose is to improve technology rather than to utilise it to raise output. I argue therefore that no increase in the volume of the capital stock takes place through investment in intangibles. If it is successful it will improve technology and make additional investment worthwhile. If it is unsuccessful it has neither volume nor value. The results of successful investment in intangibles will be an improvement in TFP. Including it in the volume of the gross capital stock will reduce the measured improvement in TFP which it was designed to produce. To see whether intangible investment has been successful it is thus necessary to exclude it when measuring the volume of the capital stock. As I also explained in my 2017

paper, this has the additional advantage of excluding the US national account data on intangibles which seem unlikely to be correctly measured.[13]

Growth models seek to identify the relative contributions from changes in labour, the volume of capital and technology. If we seek to identify the causes of technology change it would be natural at first to include intangible investment as one of the likely contributors, although it would probably then be excluded because the slowdown in TFP since 1980 has been accompanied by a large rise in intangible investment, leading to the conclusion that either it makes no significant contribution to TFP or that the data are badly measured.

Figure 2: US TFP



Sources: BEA Fixed Asset Table 1.5; NIPA Table 1.1.4; BLS; Jordà, Schularick and Taylor (2016).

Output will rise in response to the new investment but, with an unchanged labour force and no change in NTV that include profit margins, labour incomes per person will rise proportionately to output and some of the existing stock of capital will become uneconomic and be scrapped. Output

[13] I illustrate this in Figure 13 of Smithers (2017).

will rise, not because the gross capital stock has grown, but because new, more efficient capital has replaced older.

The capital/output ratio is used to measure the impact of changes in NTV on output. This ratio is volatile in the short term due to the impact of cyclical fluctuations. It is therefore necessary to measure TFP over extended periods. I show in Figure 2 the resulting estimates for TFP measured over the 20 years to the x-axis dates. TFP has been volatile, although it has fallen since the data series starts in 1952 and again since the 20-year period 1982 to 2002, after staging a sharp recovery.

Allowing for the shorter time series covered, the results are similar to those set out in my 2017 paper.

Testing the NTV Model

Investment becomes worthwhile either through TFP or through changes in the non-technology variables. Therefore it can also be calculated independently from changes in the constituents of NTV, which are profit margins, leverage, interest rates, and the rate of corporation tax and the hurdle rate on equity.

Changes in NTV are the aggregate result of changes in its constituents which are:

1. Output net of depreciation (Y).
2. The volume of capital (K).
3. Profits margins, measured by profits after depreciation but before interest and corporation tax as a percentage of output measured after depreciation (M).
4. The amount of interest paid, which is the rate of interest (I) times the amount of debt (D).
5. Leverage depends on the amount of equity (E) and capital (K).
6. The effective rate of corporation tax (T).
7. The hurdle rate on equity (H).

The interaction of NTV with the current level of technology determines the amount of capital that will be financed. This in turn is determined by the level of return on equity relative to the hurdle rate (H). Profits (Π) after depreciation but before interest and tax are:

$$\Pi = Y \times M/100$$

Profits after depreciation and interest but before tax are:

$$(Y \times M/100) - (I \times D)$$

D is the amount of K not financed by E:

$$D = K - E$$

So, profits after depreciation and interest but before tax are:

$$(Y \times M/100) - (I \times (K - E))$$

So profits after tax are:

$$(Y \times M/100) - [(I \times (K - E)] \times [(100 - T) \div 100]$$

So RoE is:

$$\{(Y \times M/100) - [(I \times (K - E)] \times [(100 - T) \div 100]\} \div E$$

NTV changes if RoE – H ≠ 0, so:

$$\Delta NTV = (\{(Y \times M/100) - [(I \times (K - E)] \times [(100 - T) \div 100]\} \div E)) - H \qquad (2)$$

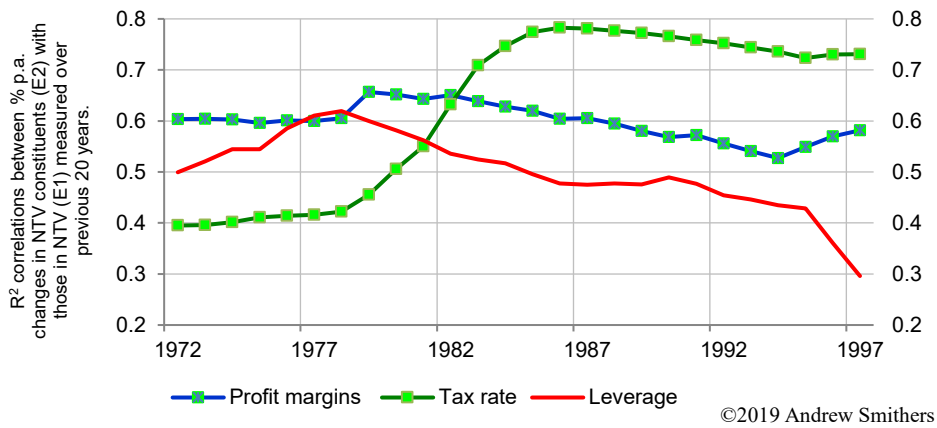
Because these two equations are based on entirely different sources of data we can test the validity of the model. Because we do not have all the data needed to solve Equation 2, we can only do this by showing that the

changes in the constituent parts of NTV are consistent with the changes in NTV derived from Equation 1.

When NTV changes, the equilibrium level of output changes. If TFP is constant, the resulting change in the rate of growth of output will depend on the speed at which the economy adjusts. As TFP is not stable this speed of adjustment cannot be measured from the data. Different rates of adjustment will not affect comparisons between Equations 1 and 2.

If we had data on corporate employment, or if all national output was from corporations, the model could be tested by comparing changes in NTV calculated from changes in employment and the volume of capital, with changes in NTV calculated from data on the constituents of NTV and the return on corporate equity (RoE). In practice, due to limitations in the available data, we can only test the model by comparing the changes in NTV that apply to non-financial companies with those for NTV as calculated for the economy as a whole.

Figure 3: US correlations between NTV (Equation 1) and 3 constituents (Equation 2).



Sources: BEA Fixed Asset Tables 1.5 and 1.9; BLS; NIPA Tables 1.1.5, 1.1.4, 1.14 and 5.2.6; Jordà, Schularick and Taylor (2016); Z1 Tables B.103 and F.103.

The correlations between changes in NTV as calculated from Equation 1 and changes in its constituents as set out in Equation 2 are strong, with the exception of interest rates, and I illustrate their changes over time in Figure 3.

Table 2: R2 correlations between changes in NTV, as calculated from Equation 1, and in the constituents of NTV, as set out in Equation 2.

	Profit margins	Apparent net cost of interest and current transfer payments	Leverage	Tax rate	RoE
1972	0.60	0.19	0.21	0.50	0.39
1973	0.60	0.19	0.21	0.52	0.40
1974	0.60	0.19	0.2	0.54	0.40
1975	0.60	0.19	0.2	0.54	0.41
1976	0.60	0.19	0.19	0.59	0.41
1977	0.60	0.18	0.19	0.61	0.42
1978	0.61	0.17	0.18	0.62	0.42
1979	0.66	0.16	0.16	0.60	0.46
1980	0.65	0.14	0.14	0.58	0.51
1981	0.64	0.11	0.11	0.56	0.55
1982	0.65	0.08	0.08	0.54	0.63
1983	0.64	0.06	0.06	0.52	0.71
1984	0.63	0.04	0.04	0.52	0.75
1985	0.62	0.02	0.02	0.50	0.77
1986	0.60	0.01	0.00	0.48	0.78
1987	0.61	0.00	0.00	0.48	0.78
1988	0.59	0.00	0.00	0.48	0.78
1989	0.58	0.02	0.02	0.48	0.77
1990	0.57	0.06	0.06	0.49	0.77
1991	0.57	0.12	0.13	0.48	0.76
1992	0.56	0.25	0.24	0.45	0.75
1993	0.54	0.39	0.36	0.45	0.74
1994	0.53	0.48	0.42	0.43	0.74
1995	0.55	0.54	0.45	0.43	0.72
1996	0.57	0.57	0.47	0.36	0.73
1997	0.58	0.62	0.50	0.30	0.73

Sources: BEA Fixed Asset Tables 1.9 and 1.5 from 1901.

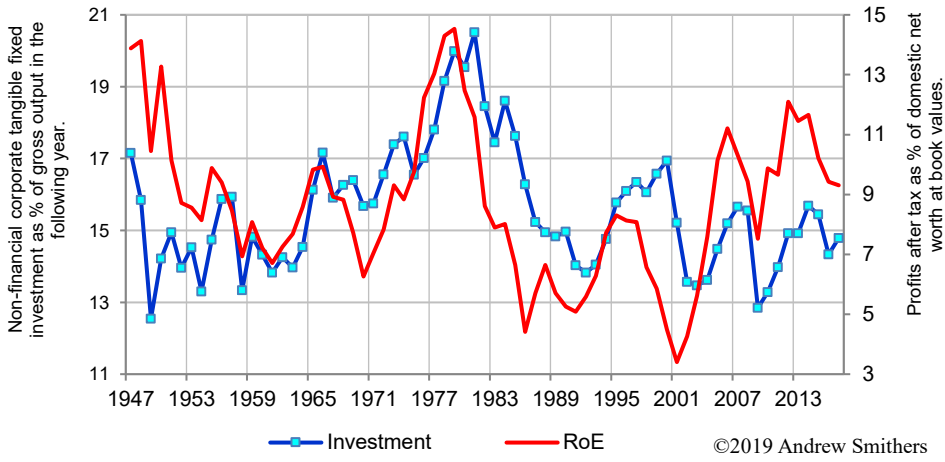
In Table 2 I show these measured over the previous 20 years for all the periods for which sufficient data are available. (NB The correlation

coefficients for the 20-year periods ending from 1988 to 1997 for the changes in the apparent interest rate paid by non-financial corporations with changes in NTV were negative. For all other constituents of NTV they were positive.)

As the changes in NTV constituents are derived independently from the changes in NTV in aggregate, significant correlations between the two are evidence for the robustness of the model and thus for the validity of the conclusions derived from it.

So long as there is no change in the hurdle rate, a high level of RoE will mean that for any level of technology there will be a high level of investment. It is therefore likely that investment will respond to changes in RoE.

Figure 4: US corporate investment and RoE



Sources: NIPA Tables 1.1.5 and 1.14 and Z1 Tables B.103 and F.103.

Figure 4 compares the tangible investment by non-financial companies as a percentage of gross output with RoE in the previous year. The latter is measured without inventory (IV) and capital consumption (CC) adjustments and with net worth at historic cost as this corresponds most closely to the information on returns available to company managements.

Over the whole period shown in Figure 4 (1947 to 2017) investment and RoE appear to be unrelated and I show this in Table 3 with the R^2 correlation being 0.112. While the relationship between investment and RoE has not been stable over the whole period, as Table 3 shows it was stable between 1968 and 2000, but not afterwards following the dramatic change in management incentives over the decade 1990 to 2000.[14]

The post-war period falls into three parts. The years 1947–1968 were those of adjustment in the aftermath of the Second World War, which had boosted profits but depressed corporate investment in order to maximise resources available for armament production. At the end of the war RoE was exceptionally high and fell, but investment was depressed and rose despite the fall in RoE (R^2 0.126). This was followed by a period from 1968 to 2000 during which the hurdle rate was stable and investment responded to the level of RoE (R^2 0.494). After 2000 investment remained weak despite the recovery in RoE (R^2 0.112) from 2000 to 2017.

Table 3: R^2 correlations between tangible fixed investment by non-financial companies as % of gross output and RoE in the previous year

1947 to 2017	0.112
1947 to 1968	0.126
1968 to 2000	0.494
2000 to 2017	0.055

Sources: NIPA Tables 1.1.5 and 1.14 and Z1 Tables B.103 and F.103.

The correlations in Table 3 compare the following year's level of investment with the current RoE. If the current level of investment is used there is a stronger correlation for all periods. It seems likely that this is due to an element of auto-correlation through the current year's investment being allowed as a deduction for corporation tax, without a full increase in depreciation yet being charged.

[14] As set out in Table 6 of Smithers (2017).

Table 4: NTV constituents in 2000 and 2017

	Profit margins	Corporation tax %	Interest %	Leverage
2000	16.83	36.59	6.6	36.65
2017	22.25	19.53	6.21	38.5

Sources: NIPA Tables 1.1.5 and 1.14 and Z1 Tables B.103 and F.103.

Table 4 shows that the changes in the measurable constituents of NTV have all encouraged higher investment. These changes have also resulted in a rise in RoE from 4.49% to 9.31%. The failure of investment to rise as much as would otherwise have been expected appears therefore to have been caused by a rise in the hurdle rate, which cannot be measured in the short term. In my 2017 paper I attributed this rise and the consequent weakness in investment after 2000 to the change that took place over the previous decade in the form and level of management remuneration.[15]

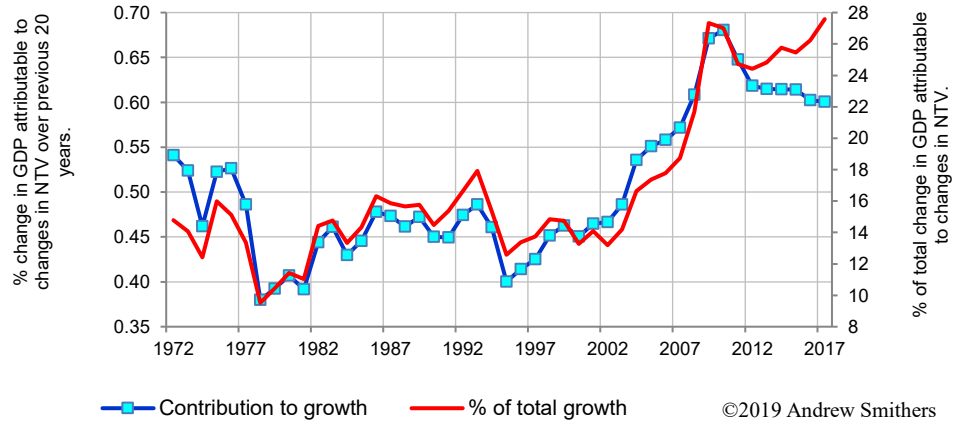
The Importance of the NTV Model for Policy

The decline in the rate of improvement in labour productivity seen since 2000 has all too often been treated by economists and financial journalists as inexplicable and consequently impervious to attempts to reverse the trend through policy changes. This attitude follows naturally from consensus growth theory, in which improvements in labour productivity are the result of changes in technology, and in 'the cost of capital'. Neither of these appear amenable to policy changes other than through changes in interest rates, which have fallen to near zero in nominal terms. As their decline has been notably ineffective in stimulating investment, and there is no apparent way to speed the rate of change in technological progress, the consensus growth model has led naturally to a negative attitude to the feasibility of policy changes to enhance growth.

[15] In *Productivity and the Bonus Culture*, to be published by Oxford University Press in July 2019, I give a fuller account of the way in which, from the viewpoint of the economy, management behaviour has responded perversely to the change in incentives.

Some economists have suggested that a higher rate of inflation would allow real interest rates to become significantly negative and the resulting fall in the cost of capital would stimulate investment and lead to faster growth. The evidence is, however, that while nominal interest rates have some impact on investment there is no observable relationship with real interest rates.[16] Others have proposed that increased spending on research and education should have a positive impact. It appears from the data on research spending that it is ineffective in the private sector, either because advantage is taken by companies to profit from tax credits by reallocating expenditure to show increases in investment in R&D which have not really occurred or because such expenditure is ineffective in improving TFP. Extra spending on education and research by government could be effective in raising growth though the effect seems unlikely to be quick while the costs, in terms of increased tax, will be.

Figure 5: US impact on growth of changes in NTV



Sources: BEA Fixed Asset Tables 1.5 and 1.9; NIPA Tables 1.1.4 and 1.1.6; Jordà, Schularick and Taylor (2016); BLS.

[16] 'Reflections on macroeconometric modelling' by Ray C. Fair, Cowles Foundation, Department of Economics, Yale University, 2015; e-mail: ray.fair@yale.edu, website: https://fairmodel.econ.yale.edu.

In contrast the NTV model suggests that growth is more readily responsive to policy changes. Figure 5 shows that over the past 20 years changes in NTV have been responsible for 28% of total growth with a contribution of 0.6% p.a. The problem is that this enhancement depends not on the level of NTV but on changes in them. Changes to improve TFP are currently difficult to implement. Leverage is high and corporation tax is low as are interest rates, changes in which appear, as shown in Table 2, to have little impact on NTV. I also showed, however, that the hurdle rate on investment appears to have risen since 2000 and policy changes to bring it back down again to its long-term historic level could therefore be highly effective in improving the trend growth rate of the economy. This could be achieved in various ways, for example by changing the way corporation tax is levied from profits after interest to profits before interest but after fixed tangible capital investment.

The change in management remuneration that occurred in the 1990s is likely to have been the cause of the rise in the hurdle rate. Bonus systems with their negative impact on investment vary. For example they appear to apply less to foreign-owned and unlisted companies. As companies with depressed investment levels are likely to lose market share to their competitors over time, current bonus systems are likely to change and, as the negative impact of these systems weakens, the hurdle rate should fall back to its long-term level. Policy measures to speed this up would nonetheless be helpful for growth.

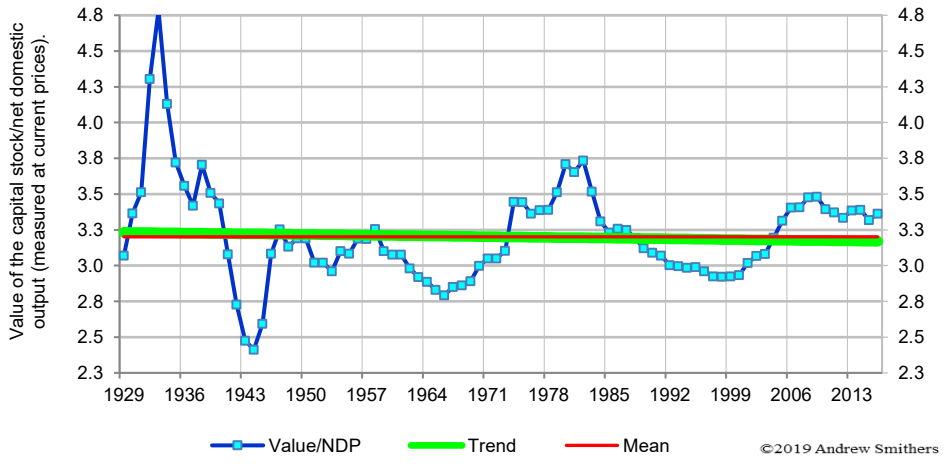
The Value of the Capital Stock

The value of the capital stock is measured by surveys, the short-term results of which will depend on cyclical fluctuations in the economy, as the value of second-hand equipment will vary with business confidence. According to the NTV model the value of the capital stock will have a constant ratio to output and, given cyclical fluctuations in the value shown by survey data, the ratio should be mean-reverting. Value equals profits (Π) after tax at some multiple (θ) of the non-technology variables, e.g. a fall in the hurdle rate on equity will have increased the value of profits proportionately to the fall. Thus $V = \Pi \times$

θNTV. Profits are the share of output that can be financed at the current level of NTV and are thus the level of output divided by some multiple (ε) of NTV: e.g. a fall in the hurdle rate will increase the level of profits proportionate to the fall. So Π = Y / (εNTV). Thus V = (Y (/εNTV)) × (θNTV) = (θ/ε) × (Y).

The NTV model thus explains the mean reversion of the value capital/output shown in Figure 6.

Figure 6: US mean reversion of capital stock value/NDP.



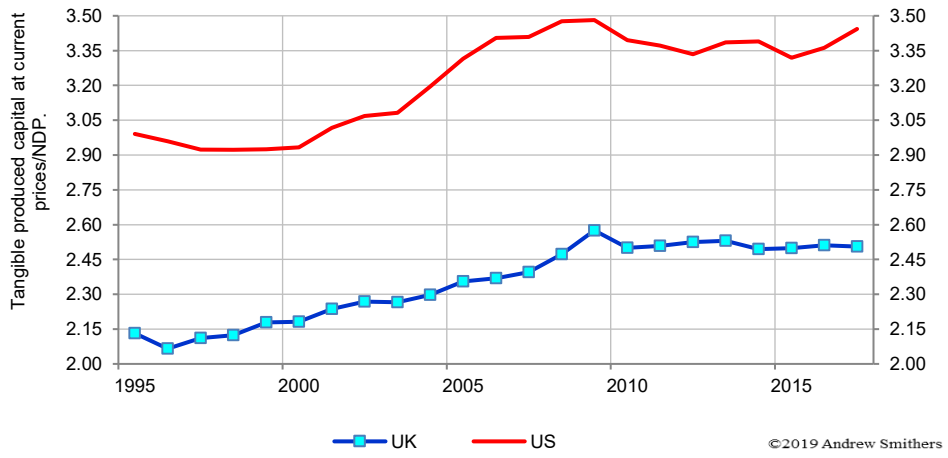
Sources: BEA Asset Table 1.1, NIPA Tables 1.1.5, 3.9.5 and 5.1.

As businesses need supporting capital, equipment will be scrapped if the return on it falls below the hurdle rate on the value of the associated land, trade credit and inventories required for output. Unlike the produced capital embedded in business equipment or housing, supporting capital has alternative use value. The result is that the produced capital is scrapped before its return becomes negative. If the equipment has some value as scrap, the point at which it will be taken out of production is even earlier.

The higher the value of supporting capital relative to output the earlier will old equipment be scrapped. High land values will therefore mean that

the efficiency of produced capital needed to pass the hurdle rate will need to be higher in countries with high land costs, unless the returns are aided by a higher profit margin. International capital flows will result in the expected returns on produced capital being the same in both countries, so high land values will need to be offset by lower produced capital/output ratios or higher profit margins.

Figure 7: UK and US capital/output ratios

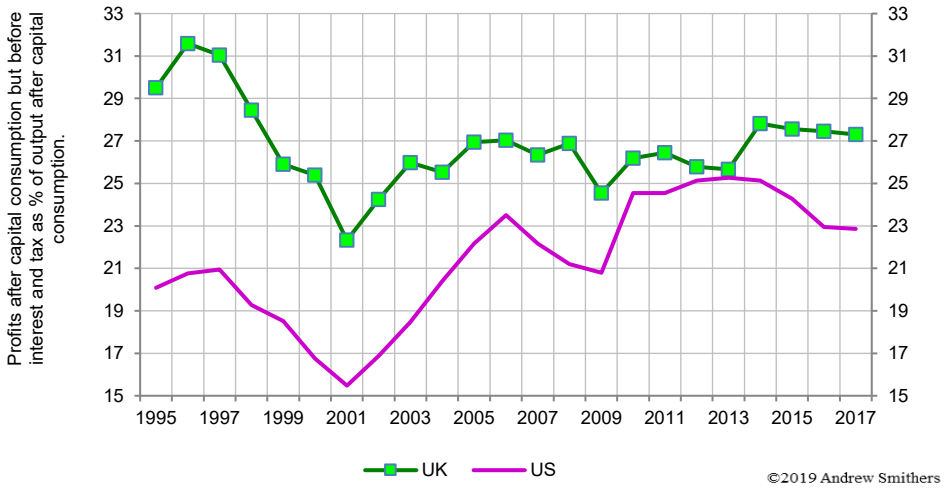


Sources: UK: Office for National Statistics (ONS) (NG22, NG27, CGRD, YBHA and NQAE); USA: BEA Fixed Asset Table 1.1 and NIPA Tables 1.1.5 and 5.1.

As I illustrate in Figure 7, the limited data available for the UK, which are available only since 1995, show that the value capital/output ratio is lower than in the USA and Figure 8 shows that profit margins are higher.

The lower UK capital/output ratios might indicate that capital is more efficiently employed in the UK than in the USA or that the price of land is higher in the UK and this causes produced capital to be scrapped earlier than in the USA. As new capital is more efficient than old this will reduce the value capital/output ratio of the UK and will do so even if the efficiency with which comparable pieces of equipment are employed in both countries is less in the UK.

Figure 8: UK and US non-financial companies' net profit margins



Sources: UK: ONS (FARR, FBDA, FACQ, JQJW and NRSK); USA: NIPA Table 1.14.

The limited UK data on the ratio of output to value of the capital stock is thus consistent with the assumption that land prices are high relative to those in the USA.

NB Excel files containing the data and calculations are available on the Smithers & Co website at www.smithers.co.uk. A ZIP file containing all the charts used can be found (and downloaded) from this link: http://www.smithers.co.uk/page.php?id=58.

I am indebted to Martin Weale for his help with this paper. If it has virtues they will owe much to him, while its faults are entirely mine.

References

Fair, Ray C. (2015). Reflections on macroeconometric modelling. New Haven, CT: Cowles Foundation, Department of Economics, Yale University. Available from https://fairmodel.econ.yale.edu/mm1.htm; accessed 10 June 2019.

Ghosh, Swati R. and Aart Kraay (2000). *Measuring Growth in Total Factor Productivity.* World Bank PREM notes No. 42, September. New York: World Bank.

Jordà, Òscar, Moritz Schularik and Alan Taylor (2016).

Òscar Jordà, Moritz Schularick, and Alan M. Taylor. 2017. *Macrofinancial History and the New Business Cycle Facts.* NBER Macroeconomics Annual 2016, volume 31, edited by Martin Eichenbaum and Jonathan A. Parker. Chicago: University of Chicago Press.

Oulton, Nicholas and Gavin Wallis (2016). Capital stocks and capital services: integrated and consistent estimates for the United Kingdom 1950–2013. *Elsevier Economic Modelling* 54.

Schreyer, Paul (2001). *The OECD Productivity Manual. A Guide to the Measurement of Industry-level and Aggregate Productivity*, No. 2. Paris: Organisation for Economic Co-operation and Development.

Smithers, Andrew (2017). Building a testable model to estimate total factor productivity. *World Economics* **18**, *2*.

Solow, R. M., J. Tobin, C. C. von Weizsacker and M. Yaari (1966). Neoclassical growth with fixed factor proportions. *The Review of Economic Studies* **33**, *2*.

Weale, Martin (2019, forthcoming). Foreword. In Andrew Smithers, *Productivity and the Bonus Culture.* Oxford: OUP.