Building a New Testable Model to Estimate Total Factor Productivity

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Key Points

- A new model to measure Total Factor Productivity free from the flaws which exist in previous models; appropriate data are used to test it.
- The model distinguishes between the contributions made to investment and growth by changes in technology and other non-technology variables.
- A key constituent of non-technology variables is the equity hurdle rate; since 2000 this has dramatically changed and thereby stifled investment and productivity.
- Reform of current management bonus arrangements is found to be essential to obviate the risk of economic stagnation.

Introduction

It is reasonable to assume that economic growth depends on changes in the supply of capital, labour and technology. Total Factor Productivity ('TFP') models, which are based on this assumption, aim to attribute the growth of the economy to changes in the volume of the labour and capital stocks and a residual known as TFP (or Multi-Factor) productivity, which represents the contribution from technology. It seems generally agreed that attempts to develop such a model have so far proved to be unsatisfactory. One reason is the practical one that 'Fairly innocuous differences in assumptions can lead to very different estimates of TFP growth'.[1] This comment raises the more

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[1] *Measuring growth in total factor productivity* by Swati R. Ghosh and Aart Kraay, published by the World Bank, PREM notes No. 42, September, 2000.

substantial issue of whether these models have any scientific validity. If even one version of these models were testable and robust, it would be accepted as the valid one superseding all others, but no such model seems yet available. The challenge is therefore to produce a model which is robust when tested and so strongly data-based that it is not sensitive to any assumptions made.

While it is possible to imagine ways in which the existing stock of capital can become more efficient, the scope for such developments seems limited. The efficiency of comparable plants varies from country to country, but so do attitudes, regulations and skills, which are difficult to change. In practice, most growth requires investment either to replicate existing equipment to meet increased demand or to install new equipment in which improved technology is embedded. We therefore need to distinguish between investment which responds to changes in technology and investment not driven by such changes. Investment is profit-driven. Improved technology raises the output of a given amount of investment and, unless offset by other changes, it raises the profitability of new investment; equally there are non-technology variables ('NTV'), which can stimulate or deter investment in the absence of any changes in technology. Models need to distinguish between these two, i.e. to differentiate between TFP and NTV. Improvements in technology can change the quality of labour or of capital. I shall treat both as part of TFP. This is simpler and avoids the difficulty of measuring improvements in the quality of labour. It should nonetheless be noted that rising levels of education and other improvements in the quality of labour may be essential for allowing improvements in capital efficiency to be implemented.

Measuring TFP and NTV

The problems with the existing models, which give rise to the World Bank's criticism, arise from the way their authors have sought to construct them. They have not used all the data that are available, but relied solely on those for past investment. This has required them to make assumptions about the speed at which the resulting plant has been scrapped. Small differences in these assumptions produce the very different results and thus the lack of credibility noted by the World Bank. I am critical of these models, not only on these but also on other grounds. Most importantly I can find no attempt to subject these models to critical tests. If any of them proved robust when tested it would be accepted in preference to the others. As they do not seem to be testable, I question whether they have any scientific validity. I also think that the lack of testability is the unnecessary result of ignoring data which, if used, would render the assumptions made about the rate at which capital is scrapped redundant. Another of my objections is that the models that I am criticising confuse the value of capital with its volume. Plant loses value over time as its profitability falls as real wages rise. But it continues to exist until scrapped and, while depreciation is rightly applied annually to estimates of value, the volume of past investment is unchanged until it is scrapped. Assuming that the volume of plant falls every year after it is installed is, in effect, an assumption that bits of it fall off every year.

New investment is risky and some part of it must therefore be financed by equity, which is, in contrast to debt, the risk-taking form. Business and households have a minimum prospective return on equity before they are prepared to venture it in new investments. This is known as the hurdle rate. The right combination of technology (TFP), which determines the efficiency of capital, with a satisfactory level of the non-technology variables (NTV) is needed for the hurdle rate to be exceeded and therefore these together determine the level of investment.

There are many opportunities for investment at any one time, and the prospective returns on them vary. The private sector, including both households and companies, will invest in those assets, such as houses and business equipment, for which the prospective returns exceed the hurdle rate. As technology changes, the efficiency of new investment will rise and, unless NTV change, more investment opportunities will pass the hurdle. Changes in TFP will therefore cause investment to rise if NTV are stable. Equally, a helpful change in NTV will cause investment to rise even if TFP is unchanged.

Changes in NTV cannot be observed directly, but they can be measured by comparing changes in the volume of the capital stock with changes in employment.

Output depends on the levels of TFP, NTV, employment and the capital stock, measured by volume. If TFP and employment are all growing at a steady rate and NTV are stable, then output and capital will all be growing at a steady rate, which will be the growth of employment plus the improvement in TFP. Without changes in NTV, the ratio of employment to the capital stock will be stable. We can therefore measure NTV from any difference in the growth of employment and the capital stock. If the capital stock grows more slowly than employment, NTV must have changed in an unhelpful way and vice versa. TFP can therefore be responsible for more than 100% of investment and growth, or less if changes in NTV are helpful.

If, for example, we assume that employment grows at 1% p.a. and there is no change in TFP or NTV, capital and output will also grow at 1% p.a., as slower growth in capital would mean that profitable opportunities for investment were not being exploited and, if capital grew faster than employment, it would be quickly reined back as investment would be taking place whose equity returns fell below the hurdle rate.

If TFP also improves at 1% p.a. and there is no change in NTV, the capital stock will grow at 1% and output will grow at 2% p.a., as the capital stock will be more efficient and its output will grow without any net additions to it. Labour productivity will improve by 1% as output will rise faster than employment. New investment will be needed to allow the improvement in TFP to be realised, but this will not increase the net capital stock as it will be matched by some scrapping of old capital. The new capital will be more efficient than the existing stock and thus have a higher return. But the return on all the capital stock will be stable as this is determined by the level of NTV, which is unchanged. The returns on some old capital will thus fall below the hurdle rate and be scrapped.

The detailed way in which the capital stock rises in line with employment but does not change with improvements in TFP, depends on whether all constituents of NTV are stable or whether they change in ways in which changes in one offset changes in others. If all the constituents are stable, then profit margins will be unchanged. When TFP improves, the output of the new capital will be greater than of the old for the same volume. For profit margins to be stable real wages must rise and this will render the returns on some old capital to fall below the hurdle rate.

If profit margins rise and NTV are stable, there must be a compensating change in its other constituents. For example, interest rates might rise or leverage fall, while the equity hurdle rate is unchanged. These changes would lower equity returns on some old capital below the hurdle rate and lead to it being scrapped.

With unchanged NTV the amount of scrapping must equal any addition to the capital stock from new investment, which is greater than the rise in employment. The new and more efficient capital will require labour but, as the growth in employment is unaffected by changes in TFP and NTV, this cannot be found unless the capital which is scrapped previously employed the same amount of labour.

For example, A of new capital may employ B people and have an output of C, which will be x% larger than the average output of old capital K. Volume is measured by original cost, so the substitution of A in new capital and the scrapping of A in old will leave employment unchanged: old capital will release B workers for employment with new capital. The efficiency of the total capital stock will then rise by (A/K) x%. As the numbers employed will be unchanged, labour productivity will rise proportionately to the relative efficiency of the new capital. The proportion of old capital being scrapped will be the same as the proportion of new capital to the total, so labour productivity will also rise by (A/K) x%. Increases in the efficiency of capital must therefore match increases in labour productivity if there is no change in NTV.

Investment can increase by more than the rise in capital productivity, but only if there is a favourable change in NTV. If that occurs additional investment, which was previously too inefficient for its returns to pass the hurdle rate, will be able to do so and will occur. Changes in NTV will allow the capital stock to grow at a different rate to that of employment. In these circumstances TFP will contribute more or less than 100% to growth, depending on whether the impact of changes in NTV are positive or negative for profitability.

This relationship will hold only if the capital stock is measured by volume and not by value. Tangible investment has embedded in it the technology of its time. Recently invested capital is more valuable than old because its technology is superior. The current value of old capital and the rate at which it falls over time depends significantly on the growth of productivity and thus on the rate at which technology improves. The value of the net capital stock thus includes an adjustment for the rate at which technology improves as well as the total amount of past investment.[2]

To assess the relative contributions of TFP and NTV we therefore need to measure the volume of the capital stock as distinct from its value. The volume of the capital stock depends on the amount, measured at original cost, of physical capital that has been invested in the past and is still being used. Its volume is unchanged until it is scrapped and it is unaffected by the level of investment in intellectual property, which adds nothing to the stock of physical capital. Depreciation measures the fall in the value of invested capital and therefore should not be deducted to arrive at volume measures. Both the volume and the current value of the capital stock are assessed by surveys.

The Office for National Statistics (ONS) describes its approach as follows:

> Gross capital stock tells us how much the economy's assets *would cost to buy again as new, or at their replacement cost.* All of the fixed assets in the economy, that are still productive and in use, are added up to calculate this. …This measure shows the value at the end of the year. This is mainly calculated as an intermediate step towards net capital stock… Net capital stock shows the market value of fixed assets. The market value is the amount that the assets could be sold for, which will be lower than the value of gross capital stocks.[3]

The US approach is the same: 'BEA bases its depreciation patterns on empirical evidence of used asset prices in resale markets wherever possible.'[4] The method used to establish the value of the capital stock does not directly depend on the impact of productivity but, through the use of surveys,

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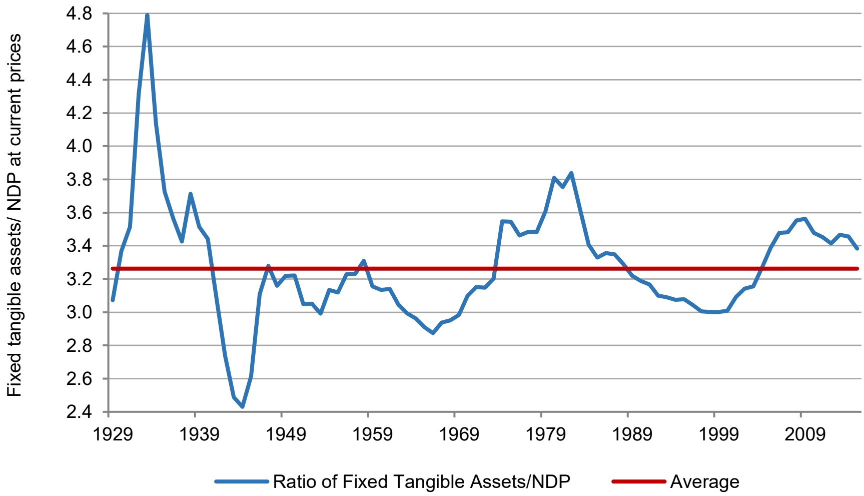
[2] *Neoclassical Growth with Fixed Factor Proportions* by R.M. Solow, J. Tobin, C.C. von Weizsacker and M. Yaari published in The Review of Economic Studies Vol. 33 No. April, 1966.
[3] *Capital stocks, consumption of fixed capital* published in the ONS Statistical Bulletin 2014.
[4] From Additional Information in BEA's Fixed Asset Table 1.1.

nonetheless allows for it. If resale values are accurately assessed they will reflect the expected returns from both old and new capital and will therefore reflect over time changes in both NTV and TFP. The value of the net capital stock thus rotates around the level of output (Figure 1) and cannot therefore be used to try to separate the different contributions to growth from changes in TFP and NTV. Cyclical fluctuations in the economy will tend to depress output more than the resale price of plant. This causes the ratio of the net capital stock to Net Domestic Product (NDP) to wobble around its long-term average.

Figure 1. US: Ratio of value of fixed tangible assets to NDP.



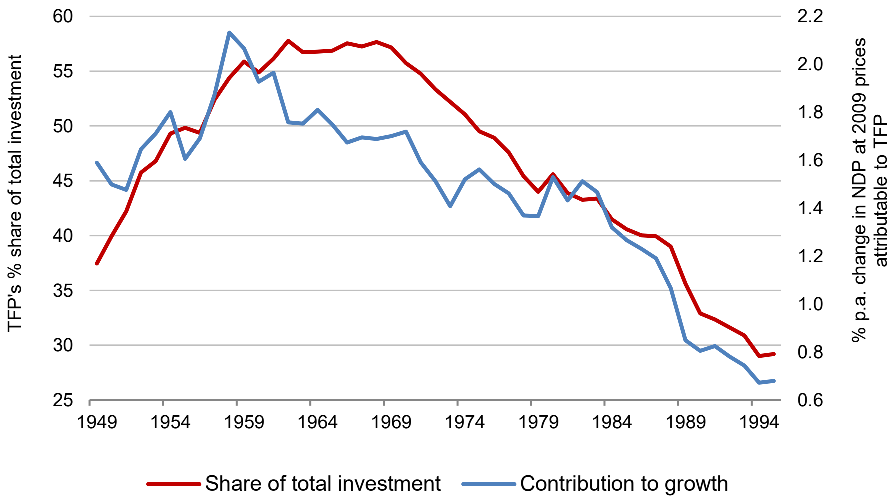
Data sources: Bureau of Economic Analysis, Fixed Asset Table 1.1 and National Income and Product Accounts, Tables 1.1.5 and 5.1.

It is not necessary to make assumptions about the initial value of the capital stock at any time or the rate at which it is scrapped, as the necessary information is available from official data. ONS data for the UK, however, are not available for long enough to be useful; I shall therefore use only US data. The actual volume data from the Bureau of Economic Analysis (BEA) do not appear to be published in this form, but they can be derived from their data on the average life of the existing stock published in BEA Fixed Asset Table 1.9. I make one assumption, which is that old capital is scrapped earlier than new. The volume can then be assessed from past tangible investment using the historic data from the BEA from 1929, supplemented by earlier data from the Bureau of the Census and other sources. The volume of the capital stock depends on the amount of physical capital that has been invested in the past. Its volume is unchanged until it is scrapped and it is unaffected by the level of investment in intellectual property, which adds nothing to the stock of physical capital.

The volume of the capital stock is all past physical investment that has not been scrapped. It is scrapped when it becomes uneconomic, but it does not cease to work through dilapidation if properly maintained. The cost of maintenance is separate from depreciation and is a separate deduction in national accounts. Depreciation and the cost of maintenance are often confused, even in economic textbooks. Physical investment does not include intangibles, which add nothing to the capital stock. If successful they contribute to changes in technology and should thus be excluded from investment when the aim is to calculate the impact of technology. Output should therefore exclude such investment and the assumed depreciation on it. I therefore follow Solow in defining output as NDP.[5]

[5] *A Contribution to the Theory of Economic Growth* by Robert M. Solow published in The Quarterly Journal of Economics, Vol. 70, No. 1 (Feb. 1956), pp. 65–94.

Figure 2. US: TFP's share of investment and contribution to growth.



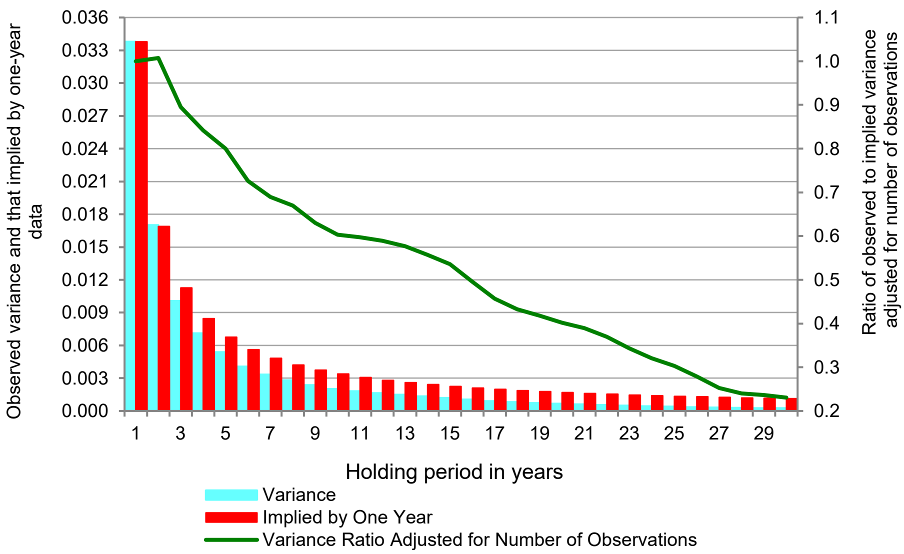
Data sources: Bureau of Labor Statistics (LNS11000000), BEA Fixed Asset Table 1.9, NIPA Tables 1.1.5, 3.9.5, 5.1 and 1.14 and pre-1929 data from the Bureau of the Census and Kuznets, etc.

The capital stock is less volatile than employment, so the difference between their growth rates fluctuates sharply from year to year. I have therefore projected the contribution of TFP to investment and growth over the next 20 years up to 2015, which is the most recent year for which data on the average age of the capital stock are available. Over the 20 years from 1995 to 2015 TFP has only contributed 0.68% p.a. to the growth of US NDP and, without a contribution from NTV, this would have been the total growth rate of the economy.

The Constituents of NTV

These variables are the required return on equity capital, the cost of debt, leverage (the proportions of equity and debt used to finance investment), profit margins and the rate of corporation tax. Corporate investment is affected by all these variables, but profit margins and corporation tax do not affect the household sector's investment in housing. Changes in any of these will cause changes in the level of investment and growth independent of changes in technology. All fluctuate in the short term but two, the cost of equity and profit margins, are stable over the long term.

Figure 3. US: Variance compression of real equity returns 1801 to 2013.



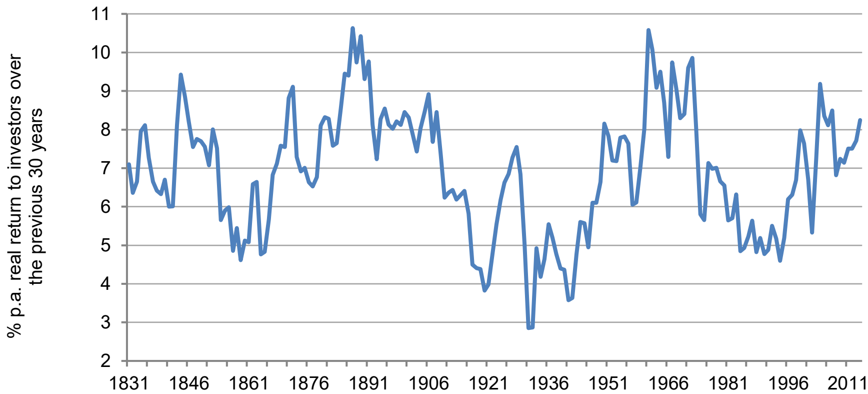
The volatility of equity returns exhibits negative serial correlation, as I illustrate in Figure 3.[6] This shows that the stock market does not follow a random walk with drift. After periods when they have been high real returns tend to fall and vice versa, which therefore indicates that they are mean-reverting. Figure 4 illustrates this in another way and shows that past returns rotate around an average of about 6% p.a. This therefore must also be true of

[6] NB: If we had an infinite number of observations and returns followed a random walk the ratio between the actual and implied variance would always be one. If we have T observations then the expected variance ratio at year n would be (T–n+1)/T. I have therefore adjusted the ratio for the number of observations. A virtually identical pattern to that of Figure 3 is shown if volatilities are measured over different periods, for example if the data are restricted separately to the nineteenth or twentieth centuries.

the real return on corporate equity ('RoE') and over the long term companies must invest in new capital to the point where RoE falls to this level but no lower.[7]

A real return on equity of around 6% p.a. is thus the long-term hurdle rate which determines the level of new investment. Equity is more expensive than debt, and the gap arising from differences in short-term volatility of returns is amplified by allowing interest on debt as an expense for corporation tax. It follows that the cost of capital is strongly influenced by leverage, being the ratio of net debt to output.

Figure 4. US: Real equity returns over previous 30 years.



Data sources: Jeremy Siegel, Elroy Dimson, Paul Marsh and Mike Staunton, MSCI, ONS and BLS.

Figure 4 shows that in the US the real return to shareholders has rotated around 6% and there have been large and completely unrelated changes in the rate of corporation tax over this period, which could not have occurred if changes in corporation tax affected the hurdle rate for equity finance.[8] Both

[7] For a more detailed explanation see *Wall Street Revalued – Imperfect Markets and Inept Central Bankers* by Andrew Smithers published by John Wiley & Sons Ltd 2009.
[8] There was no corporation tax in the US during the nineteenth century as attempts to introduce it were declared unconstitutional. This continued until the 16th Amendment was passed in 1909.

the rate of corporation tax and the hurdle rate are thus independent variables which need to be included in NTV.

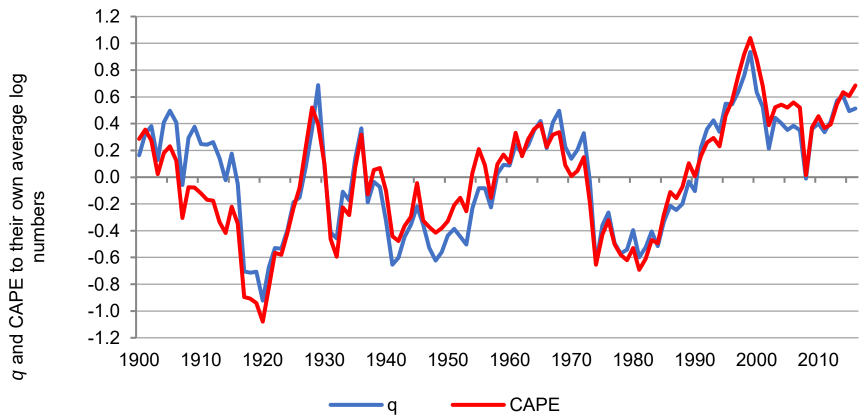
It will of course be cheaper to raise equity when the market is overpriced and more expensive when the market is cheap. The benefit of raising cheap equity is permanent and unaffected by subsequent fluctuations in share prices. The money can be raised either through new issues or less directly from shareholders through lower dividends. (Equity can also be reduced by buy-backs.) The cost of equity capital therefore fluctuates with the level of the stock market, but has no effect on the hurdle rate for new investment. Companies do not seek to raise equity when it is cheap, as doing so tends to depress share prices, which shareholders dislike. They are more inclined to reduce equity when it is expensive through buy-backs.

At any particular time the cost of equity capital, for companies on average, will therefore depend on the long-term return on them and on their fluctuations in value. While the cost of equity has been stable over the long term, its current cost changes with the level of share prices. It is below average when they are high and vice versa. To assess the current cost of equity we therefore need to know two things. The first is the long-term average return to shareholders, provided that this average is stable over time and actual returns rotate around it. The second piece of information we need is the extent to which the market is currently above or below its average level. Figure 4 shows that the first condition has been observed in the past. Real returns to shareholders have rotated around a long-term average of about 6%.

The second requirement, which is that we can measure the degree to which the stock market is cheap or expensive, is also met. There are two valid ways of measuring the value of the stock market,[9] and we have sufficiently reliable data to be able to calculate that the stock market was around 70% to 90% overvalued at the end of December 2016, as I illustrate in Figure 5.

[9] For an explanation of these two measures, which are known as *q* and CAPE, see *Valuing Wall Street* by Andrew Smithers and Stephen Wright, published by McGraw-Hill (2000) and *Wall Street Revalued* by Andrew Smithers, published by Wiley (2009).

Figure 5. US stock market value.

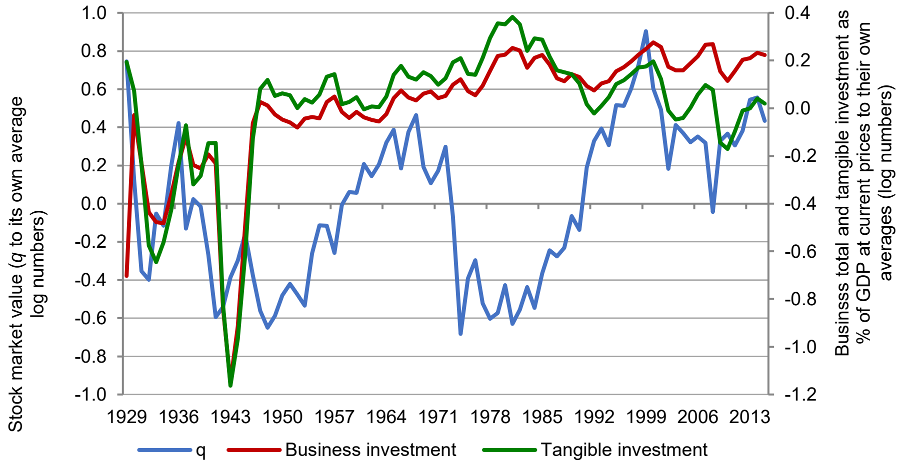


Data sources: For *q* Stephen Wright, 1900 to 1945, and Federal Reserve, Z1 Table B.103 to Q4 2016. For CAPE Robert Shiller updated.

The current cost of equity will then, on average, be this long-term rate adjusted for fluctuations in the stock market around its average, or 'fair' value. For example, as the real return to shareholders has rotated around 6% p.a. and when the US stock market is around 70% overpriced, the cost of equity capital today should be around 3.5% real (i.e. 6% divided by 1.7).[10] The current cost of equity at any time will thus fluctuate in line with the market's current degree of over- or under-valuation.

[10] This does not mean that this will be the return to investors, which will vary with how long the investment is held, whether dividends are reinvested and, if so, the level of the market when the reinvestment takes place.

Figure 6. US: Business investment and the cost of equity.



Data sources: Stephen Wright, Federal Reserve Z1 Table B.103 and NIPA Table 1.1.5.

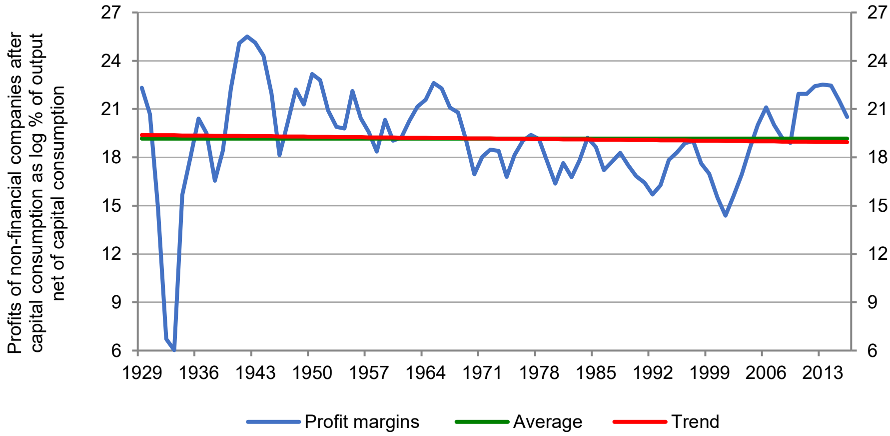
In Figure 6 I compare the fluctuations in the current cost of equity with the levels of both total and tangible business investment, comparing both with their average levels. Equity moved from being cheap in 1968 to very expensive by 1985 and then increasingly cheap.

Over the post-war period as a whole equity has become much cheaper. It does not appear, however, that the cost of equity has had any influence on investment over the longer term. This indifference to the cost of equity shows that models which assume that investment will respond to the cost of capital, of which equity is the most important part, are testable but do not work.

Figure 7 illustrates the stability of profit margins for non-financial companies from 1949 to 2015, which accords with the Cobb-Douglas production function.[11]

[11] Figure 4 shows profit margins measured with the capital consumption (CC) adjustment, but there is no significant difference if margins are measured without the CC adjustment.

Figure 7. US non-financial companies' profit margins.



Data source: NIPA Table 1.14.

Testing the Model

I have set out a TFP model which seeks to avoid the criticisms to which existing models have been subject. I have avoided the criticism that small differences in assumptions produce significant difference in results by using the data provided by the BEA for past investment and the current average life of the existing capital stock.

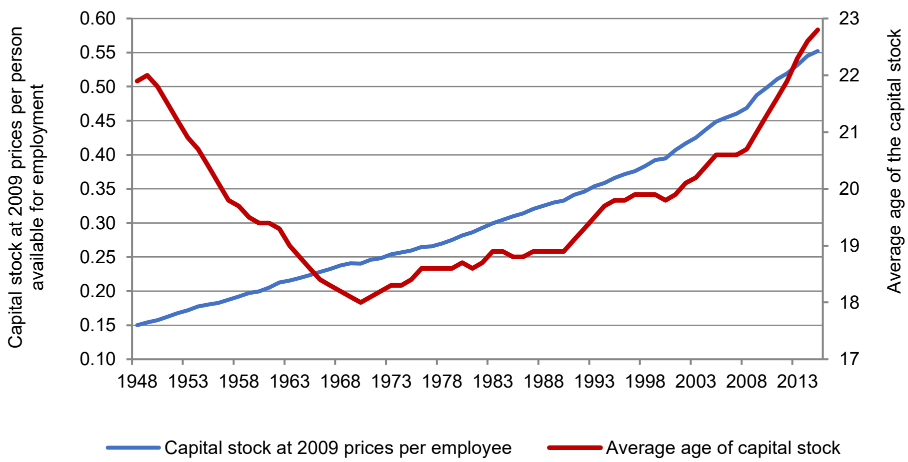
Table 1. Changes in measurable constituents of NTV.

	1949	2015
Profit margins	23.70%	24.00%
Leverage	23%	91%
Short-term nominal interest rates	1.10%	0.23%
Long-term nominal bond yields	2.36%	1.89%
Short-term real interest rates	1.90%	-0.90%
Long-term real bond yields	3.20%	1.00%
Corporation tax with IV and CC	36.50%	32.60%
Corporation tax without IV and CC	36.20%	24.50%

Data sources: NIPA Tables 1.1.5 and 1.14, Federal Reserve Z1 Table B. 203, Bank of England and Robert Shiller's website.

I also need to show that my model is testable and robust. Figure 2 shows that TFP contributed less than 100% to growth throughout the post-war period, with its contribution to total investment increasing from 1949 to 1969 and then falling. The contribution from NTV was thus positive throughout. A simple test for the model is therefore that the measurable constituents of NTV should have encouraged investment and Table 1 shows that in every case they did. In broad terms this is satisfactory but, while it passes an important test, it does not constitute a rigorous test and I therefore set out below one that is.

Figure 8. US: Capital stock per employee and its average age.

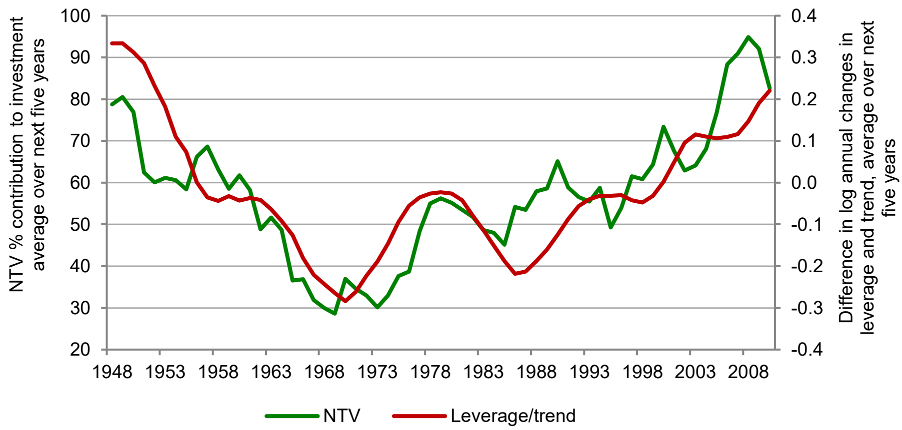


Data sources: BLS (LNS11000000), BEA Fixed Asset Table 1.9.and NIPA Tables 1.1.5, 3.9.5, 5.1 and 1.14.

Figure 8 shows that the rate at which capital is scrapped has not risen in response to a rise in the average age of the capital stock, so its volume per employee has risen steadily. As the volume of the capital stock per employee rises, the level of investment needed to maintain a stable ratio of capital per employee rises. If there is no change in NTV their contribution to growth will therefore fall towards zero. A constant change in NTV will result in a stable contribution to growth, but for the contribution to rise NTV must accelerate. Figure 2 shows that the contribution of TFP rose from 1949 to 1959. As all investment is attributable either to NTV or to TFP, the contribution from NTV has thus first fallen and then risen and has risen over the whole period.

The model therefore predicts that NTV have accelerated over the whole period and that changes in their contribution to investment will have moved with changes in the rate of growth of their participants. We cannot observe short-term changes in the hurdle rate for RoE, but if NTV have accelerated in total then at least one of their constituents must have done so and the impact cannot have been offset by significant negative contributions from other constituents.

Figure 9. US: Changes in the growth rate of net corporate debt and with NTV's share of investment.



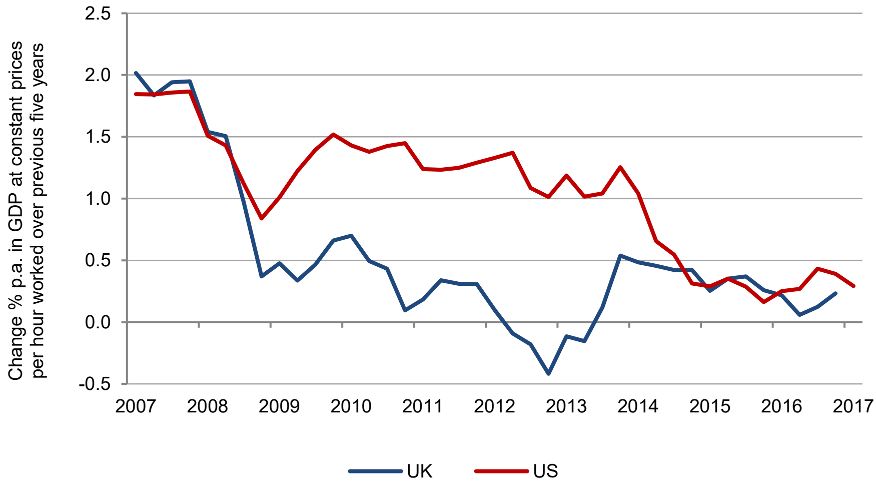
Data sources: BLS (LNS11000000), BEA Fixed Asset Table 1.9, NIPA Tables 1.1.5, 3.9.5, 5.1 and 1.14 and Federal Reserve Z1 Table B.103.

Figure 9 shows that one constituent of NTV, non-financial corporate leverage, has behaved in the way predicted. In order to measure the rate of change of leverage, I have compared the annual log changes with their trend rate. (When the difference is positive the level of leverage has been on an accelerating trend even if, compared with the previous year, the rate of acceleration has declined.) The R^2 correlation between leverage and NTV's share of investment, 100% minus the non-TFP portion illustrated in Figure 2, is 0.60. As this is predicted, it provides a test for the model under which it appears robust.

Implications for Growth

The rate of improvement in labour productivity in the UK and the US has fallen to a very slow level (Figure 10). The latest data are for Q1 2017 and show that over the previous five years UK GDP per hour has risen at 0.16% p.a. and that of the US at 0.29% p.a. For improvement to take place either TFP must improve or changes in NTV must have a positive impact.

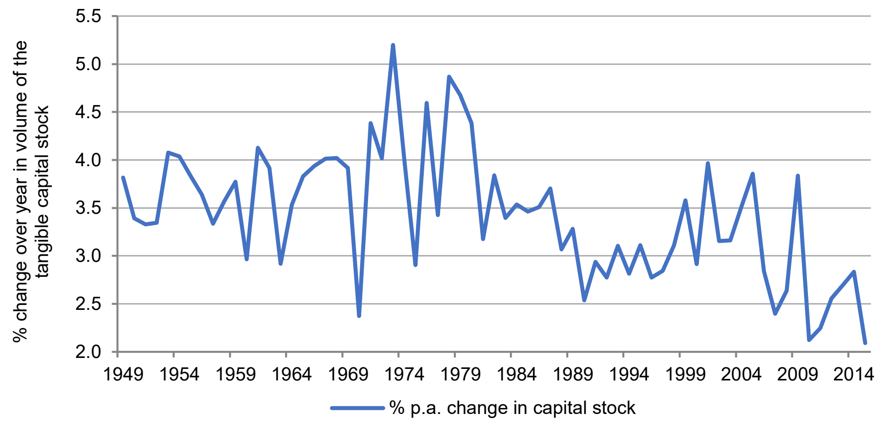
Figure 10. UK and US: Labour productivity.



Data sources: ONS (YBUS and ABMI), NIPA Table 1.1.6 and BLS special requests Table 10.

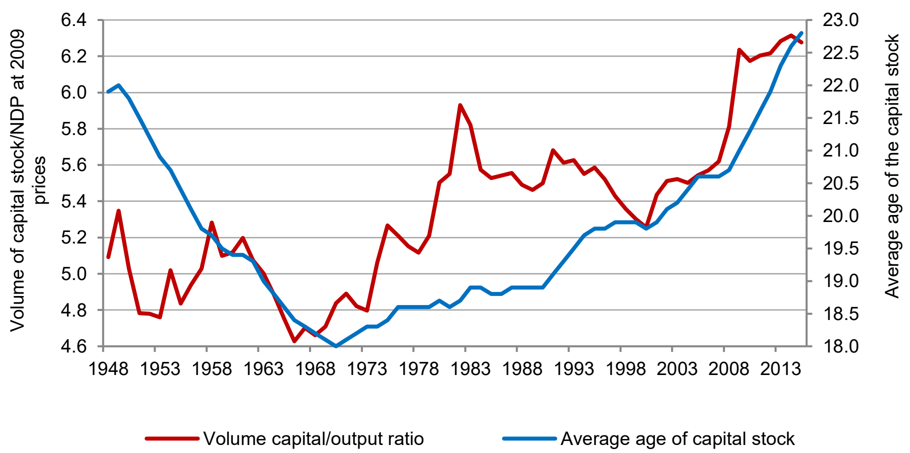
The growth in tangible volume capital stock has been slowing (Figure 11), and the average age of the capital stock has been rising (Figure 12) and was 23 years in 2015. Partly due to ageing, the result of a lower scrapping rate, and partly due to the current level of investment being higher than it was in 1992 (i.e. 23 years before), the capital stock rose by 2% in 2015.

Figure 11. US: Annual % changes in the volume of the capital stock.



Data sources: BLS (LNS11000000), BEA Fixed Asset Table 1.9, NIPA Tables 1.1.5, 3.9.5, 5.1 and 1.14 and pre-1929 data from the Bureau of the Census and Kuznets, etc.

Figure 12. US: Volume capital/output ratio and average age of the capital stock.



Data sources: BEA Asset Table 4.9 and NIPA Tables, 1.1.5 and 3.9.5.

Table 2. Changes in US capital stock measured by volume and GDP. 2009 prices.

2016 tangible investment	$2,410 bn
2015 tangible capital stock	$8,6761 bn
1993 tangible investment	$1,507 bn
Net addition to capital stock volume	$904 bn
Increase in the capital stock with no change in average age	1.04%
Increase in NDP with unchanged capital/output ratio	1.04%
Increase in numbers of people of working age	0.40%
Increase in capital stock per person at work, assuming no changes in participation or unemployment rates	0.64%

(Data sources as in charts.)

Figure 12 shows that the average age of capital stock has been rising in recent years, and that this has been accompanied by a rise in the capital/output ratio (R^2 correlation from 1970 to 2015 was 0.66). The two do not necessarily move together as the rate of change in the efficiency of new capital varies. It is nonetheless probable that changes in the average age and the capital/output ratio will move together. If therefore the average age continues to increase it is likely to be accompanied by a rise in the capital/output ratio, so that it will take an increasing amount of additional capital to achieve a given rise in output. On the other hand, if the average age stops rising the increase in NDP from the current level of investment will only be 1.04%, as shown in Table 2. Thus, whether or not the rise in the average age continues, the trend rate of growth for the US economy at current levels of investment is thus likely to be around 1% p.a.

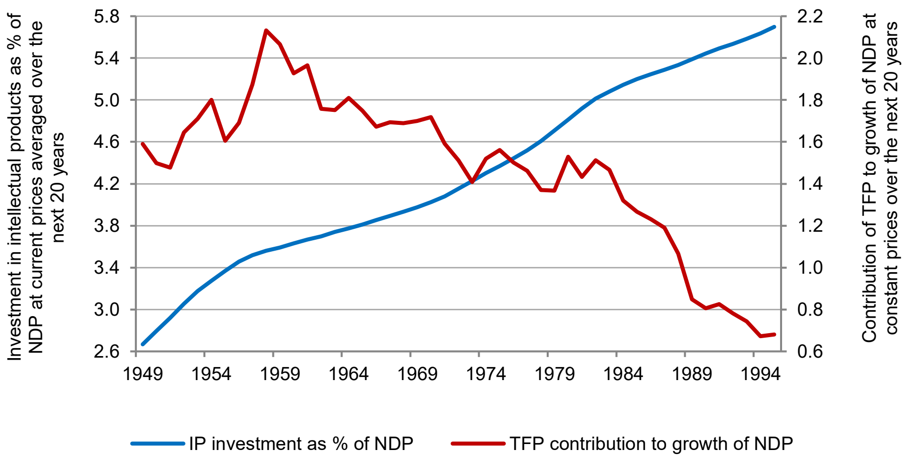
Another way of assessing growth potential is from the mean reversion of the tangible value/NDP ratio which, as Figure 1 shows, is mean-reverting and currently a bit above average. The net addition to the value of tangible capital stock in 2015 was 0.9%, which is thus the likely trend growth rate. Calculations derived from both volume and value of the capital stock thus give very similar estimates of US trend growth. The trend growth rate thus estimated, of 1% p.a., is higher than the contribution of TFP over the past 20 years, of 0.7% (projections from Figure 2), indicating a positive contribution to growth from NTV.

Improving TFP

As the trend growth rate of the US, and by implication that of the UK, are so poor policy measures are needed to improve it either through changes in TFP or NTV.

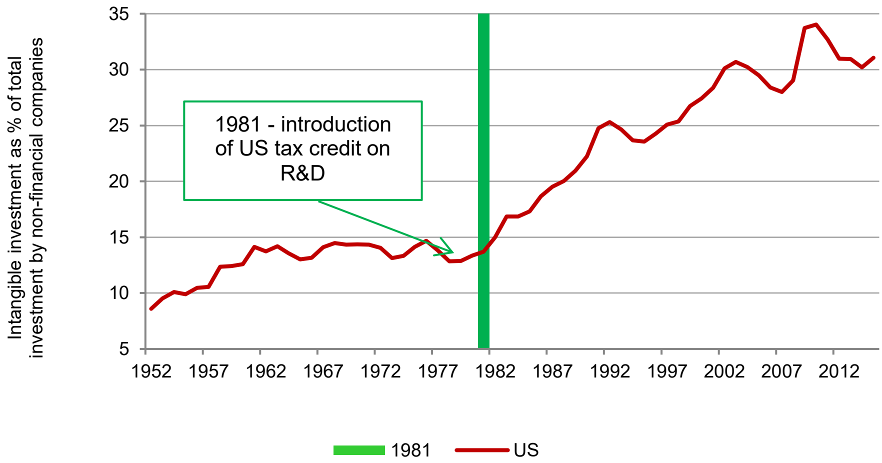
The rate at which TFP changes may simply be a matter of luck or it may respond to increased expenditure on technology. Figure 13 shows that TFP has deteriorated steadily while the proportion of NDP invested in intellectual products has risen steadily. Either the latter is mis-measured or improvements in TFP are not explained by expenditure on technology.

Figure 13. US: Investment in intellectual products and TFP's contribution to growth of NDP.



Data sources: For TFP as in Figure 2, for IP NIPA Tables 1.1.5, 3.95 and 5.1.

Figure 14. US: Non-financial companies' intangible investment as % of total.

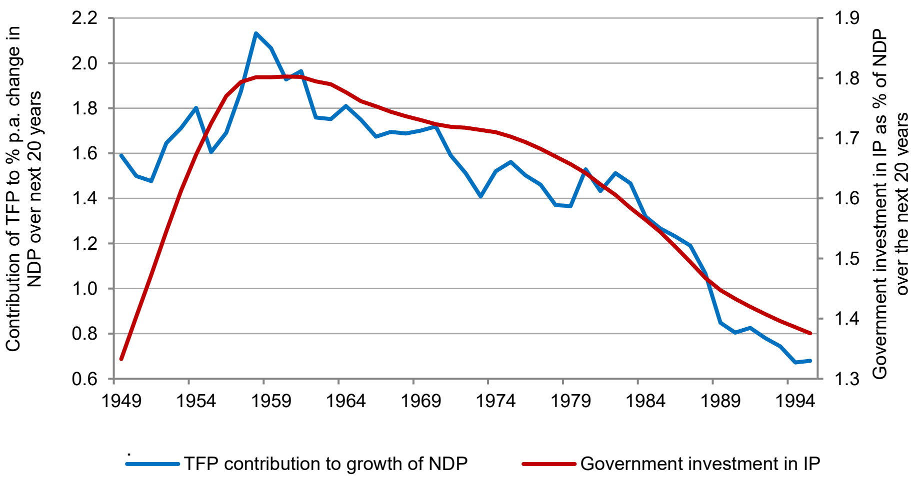


Data sources: ONS (FDBM, L5ZG, FDBA and NRJK) and NIPA Tables 1.1.5 and 1.14.

The data indicate a strong possibility that investment in IP is mismeasured. The tax credit for R&D was introduced in 1981. Figure 14 shows that private sector spending on IP averaged 13% of total investment for 20 years before that and has since risen to over 30%. It is likely that the rise in the amount attributed to R&D investment in the national accounts does not represent the extent to which expenditure on research has actually increased, but is simply a renaming of spending. Anecdotal evidence points to companies 'gaming the system' by categorising an increasing part of the salaries and other costs of employees, which were previously treated as general expenditure, as being investment in R&D. If the data used by companies in their tax returns are treated by the national accountants as being a fair measure of R&D expenditure, the result will be a rise in investment and GDP as shown in the data, but which does not necessarily represent a real increase.

It therefore seems likely that the rise shown in the national accounts in the expenditure by companies on intellectual products is driven by a change in the designation of expenses from general management to R&D. Prior to 2013 most investment in R&D and other forms of intellectual property were treated in the national accounts as intermediary expenditure. The change, which has included the revision of earlier data, has increased the recorded growth of GDP, the proportion invested and the measured rate of depreciation.

Figure 15. US: Government investment in intellectual products and TFP's contribution to NDP growth.



Data sources: For TFP as in Figure 2, for IP NIPA Tables 1.1.5, 3.95 and 5.1.

There is no similar distortion in the way that government expenditure on IP is measured and Figure 15 shows that such expenditure has moved with the contribution of TFP to growth. This is encouraging in that it suggests that changes in TFP are not simply random but respond to increased investment in intellectual property provided that this is properly measured.

It also underlines the probability that intellectual property investment in the national accounts is seriously overstated.

The data thus suggest that it will be very difficult to improve the rate of change of TFP by policy measures. Increased government expenditure on IP investment should help, but incentives for such investment in the private sector will need to be radically changed so that they produce real increases rather than accounting changes which have no substantive impact and are purely designed to lower the amount of corporation tax paid.

Improving NTV

Table 3. R^2 correlations between interest rates, bond yields and tangible investment.

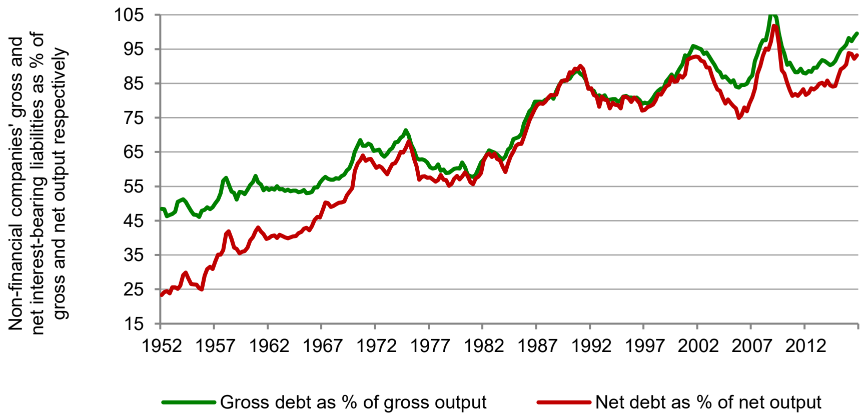
Real short-term interest rates	0.07
Nominal short-term interest rates	0.36
Real long-term bond yields	0.02
Nominal long-term bond yields	0.28

Data sources: Federal Reserve, Robert Shiller's website, NIPA Tables 1.1.5 and 3.9.5.

As a rise in the rate of change of TFP appears so difficult, improving investment and labour productivity must rely on beneficial changes in NTV. This will now be difficult in the current economic environment. Nominal interest rates cannot fall much further and it appears from macro-economic analysis that investment does not respond to changes in real rates.[12] I also show in Table 3 that there have been no significant correlations between real interest rates and the level of investment.

[12] *Reflections on macro-econometric modelling* by Ray C. Fair, Cowles Foundation, Department of Economics, Yale University, New Haven, CT 06520-8281, USA, e-mail: ray.fair@yale.edu, website: fairmodel.econ.yale.edu.

Figure 16. US: Non-financial companies' leverage.



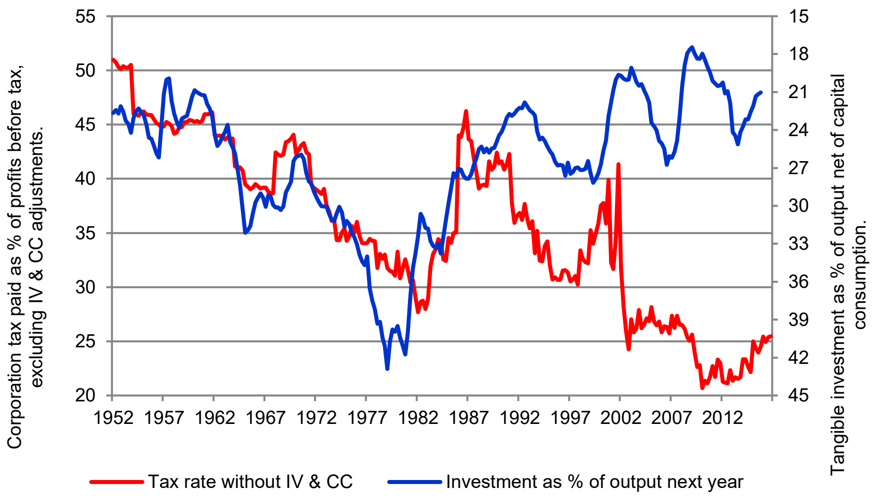
Data sources: NIPA Table 1.14 and Federal Reserve Z1 Table B.103.

Corporate leverage is nearly back to the peak it reached in 2009, which proved to be a very dangerous level (Figure 16).[13] Profit margins are mean-reverting and above average (Figure 7). They could rise further but are not readily amenable to improvement through policy changes. This leaves corporation tax and the required return on equity as the most promising routes through which beneficial changes in NTV might be achieved.

Figure 17 compares the effective level of corporation tax from Q1 1952 to Q4 2016 with the level of non-financial corporate tangible investment, measured as a percentage of the sector's output. (I have inverted the scale for the effective tax rate, to make the relationship more obvious to the eye). Figure 17 shows that investment rose as the effective rate of corporation tax fell from 1952 to 2000, but that there has since been no helpful correlation.

[13] RoEs are measured by net worth at historic cost divided by net profit after tax, excluding IV and CC adjustments, which are the data series which approximate most closely to those available to companies' management.

Figure 17. US: Non-financial companies' tangible investment and tax rate.



Data sources: NIPA Tables 1.1.5 and 1.14

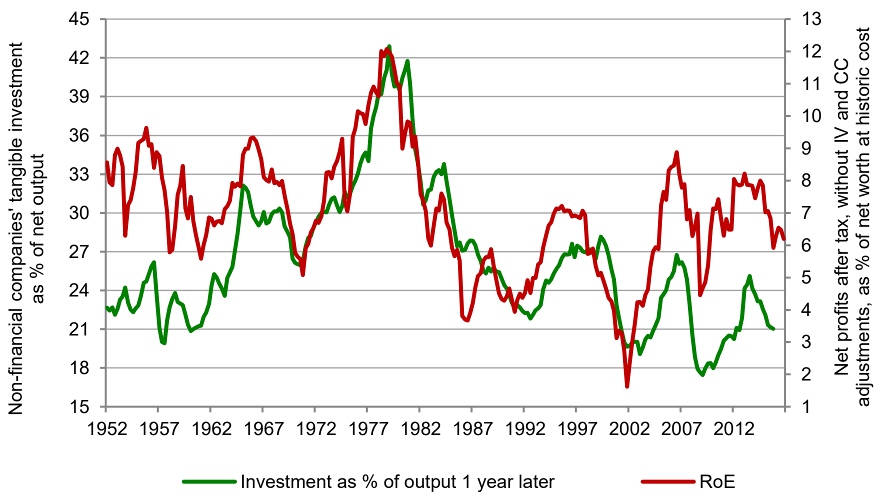
Table 4. Correlations between US non-financial companies' tangible investment and effective corporation tax.

Coefficients of correlation	Coincident	Investment one year later	Investment two years later
Q1 1952 to Q4 1999	–0.62	–0.63	–0.6
Q1 2000 to Q4 2016	0.6	0.22	–0.18
R^2			
Q1 1952 to Q4 1999	0.39	0.39	0.36
Q1 2000 to Q4 2016	0.36	0.05	0.03

Data sources: For TFP as in Figure 2, for IP NIPA Tables 1.1.5, 3.95 and 5.1.

Table 4 shows that the coincident relationship between investment and the tax rate was actually perverse from Q1 2000 to Q4 2016, with a relatively low tax rate being combined with a low level of investment. When the effective tax rate is compared with current and future levels of investment, there was a significant helpful correlation before 2000 and none afterwards.

Figure 18. US: Non-financial companies' RoE and tangible investment.



Data sources: Federal Reserve Z1 Tables B.103 and F.103 and NIPA Tables 1.1.5 and 1.14.

Figure 18 shows that there has been a similar breakdown in the relationship between investment and RoE. From 1952 to 2000, and particularly from 1972 to 2000, investment responded positively to high levels of RoE but, as Table 5 shows, since then there has been no significant relationship.

Table 5. R^2 correlations between non-financial companies' fixed tangible investment and their RoEs.

	Coincident	Investment one year later	Investment two years later
Q1 1952 to Q4 1999	0.26	0.38	0.4
Q1 1972 to Q4 1999	0.54	0.76	0.82
Q1 2000 to Q4 2016	0.01	0.17	0.25

(Data sources as in Figure 16.)

Changes in corporation tax and the RoE had an important influence on the level of investment prior to 2000 but not since. Unless there has been a sudden and dramatic decline in the TFP, which is both unlikely and not apparent in the data (Figure 2), this must have been the result of an adverse change in one of the constituents of NTV.

Table 6 shows that, for the purpose of encouraging investment, all the measurable constituents of NTV improved from 2000 to 2016. It thus seems extremely probable that the one unmeasurable constituent, which is the required return on equity, rose sharply and sufficiently to offset the beneficial impact of all the others.

Table 6. Measurable constituents of NTV in 2000 and 2016

	2000	2016
Interest rates	5.2	0.05
Net corporate debt as % of net output	80.28	89.44
Gross corporate debt as % of gross output	90.25	98.85
Tax rate with IV and CC	41.81	37.77
Tax rate without IV and CC	32.43	25.3
Profit margins	15.49	20.5

Data sources: Bank of England, Federal Reserve Z1 Table B. 103 and NIPA Table 1.14.

The rise in the required RoE represents a change in management behaviour and this is readily explicable in terms of the preceding change in incentives. As Table 7 shows, the average remuneration of US CEOs rose sharply from 1992 to 2000, accompanied by a sharp rise in the non-salary proportion, and then flattened. This change in incentives had the natural effect of changing behaviour, with some time lag between the two being likely. The benefits for management that come from improving short-term profits have risen sharply relative to the longer-term rewards from investment. This has had the effect of discouraging investment and acts in a similar way to a rise in the hurdle rate on equity.[14]

Table 7. US average CEO remuneration $ millions at 2000 prices.

	Total	Of which % salary	% bonuses, etc.
1992	2.3	42	58
1994	2.8	34	66
1996	3.6	28	72
1998	4.9	23	77
2000	6.4	17	83
2002	6.3	20	80
2004	6.5	17	83
2006	7.0	16	84
2008	6.1	17	83

Data source: National Bureau of Economic Research working paper 16585.

Conclusions

I have set out a model, which distinguishes between investment which is driven by improvements in technology (TFP) and other non-technology variables (NTV), and which avoids the two major objections to previously proposed models. Most importantly it is testable and robust when tested.

[14] For detailed explanation see *How Managerial Incentives Affect Economic Performance* by Andrew Smithers published in *World Economics*, Vol. 17, No. 1, January–March 2016.

On the basis of the model it appears that there has been a sharp change in management behaviour and that, without this change being reversed, it will be difficult to increase significantly the level of investment in the US and thereby the rate at which labour productivity and output can improve. The UK has experienced a similar change in management remuneration to that shown in Table 7, and a deterioration similar to that in the US in terms of investment and productivity. It is therefore likely that the decline in the trend growth of the UK is also due to the perverse impact of the bonus culture. It is of course unfortunate the poor quality of UK data does not permit this to be tested.

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