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Innovation, research and the UK's productivity crisis.

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Introduction

The UK is in the midst of an unprecedented peacetime slowdown in productivity growth, which comes on top of the nation's long-standing productivity weakness compared to the USA, France and Germany. If this trend continues, UK living standards will continue to stagnate and the government's ambition to eliminate the deficit will fail. Productivity growth is connected with innovation, in its broadest sense, so it is natural to explore the connection between the UK's poor productivity performance and the low R&D intensity of its economy. More careful analyses of productivity look at the performance of individual sectors and allow some more detailed explanations of the productivity slowdown to be tested. The decline of North Sea oil and gas and the end of the financial services bubble have a special role in the UK's poor recent performance; these do not explain all the problem, but they will provide a headwind that the economy will have to overcome over the coming years. In response, the UK government will need to take a more active role in procuring and driving technological innovation, particularly in areas where such innovation is needed to meet the strategic goals of the state. We need a new political economy of technological innovation.

The scale of the UK's productivity problem

The current stalling of productivity growth is probably the UK's most serious current economic problem. In terms of output per hour, the last five years' productivity performance has been by far the worst period in the last 45 years.

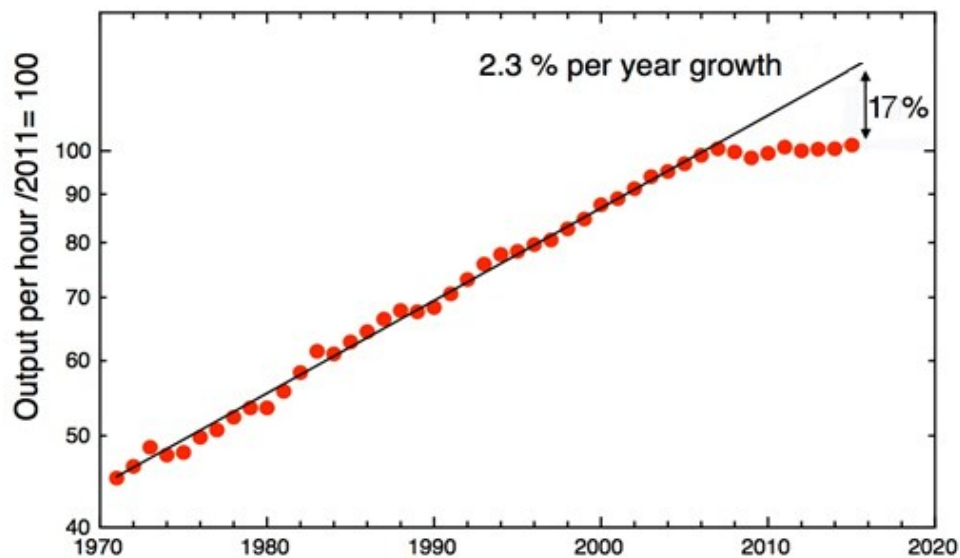


Figure 1. Labour productivity since 1970. The line is a least-squares fit to the 1970-2007 data of an exponential function corresponding to constant growth of 2.3% a year. ONS data.¹

Figure 1 shows the UK's labour productivity – defined as the GDP generated per hour worked – since 1971. What is striking about this graph is how closely productivity has followed a trend of constant 2.3% a year growth over the period 1971-2008.

This period saw many significant economic events; in the 1970s, the three day week, the bursting of the Barber boom, the IMF bail-out, the Winter of Discontent, the deep early 80s recession, the subsequent recovery, the bursting of the Lawson boom, and the recovery that followed leaving the Exchange Rate Mechanism. Yet these events are reflected in the productivity data as, at most, small perturbations around the constant trend.

This steady progress changed abruptly with the financial crisis in 2008. Since then productivity growth has essentially stopped.

Many other developed economies have had disappointing productivity growth in recent years,² but the UK's record is particularly bad. Figure 2 shows labour productivity across the G7 nations since 1970. This data, from the OECD, has been converted into constant US dollars at purchasing power parity; one should be aware that these currency conversions are not completely straightforward. Nonetheless, the picture is very clear. On this semi-logarithmic plot, a constant annual growth rate will produce a straight line. Instead, what we see is a systematic slow-down in the growth rate as we go from 1970 to the present day. The data has been fitted to a logistic function, which is a good representation of growth that starts out exponential and starts to saturate. In 1970, labour productivity in the G7 nations was growing at around 2.9% annually, but by the present day this had dropped to an annual growth rate of 1.2%.

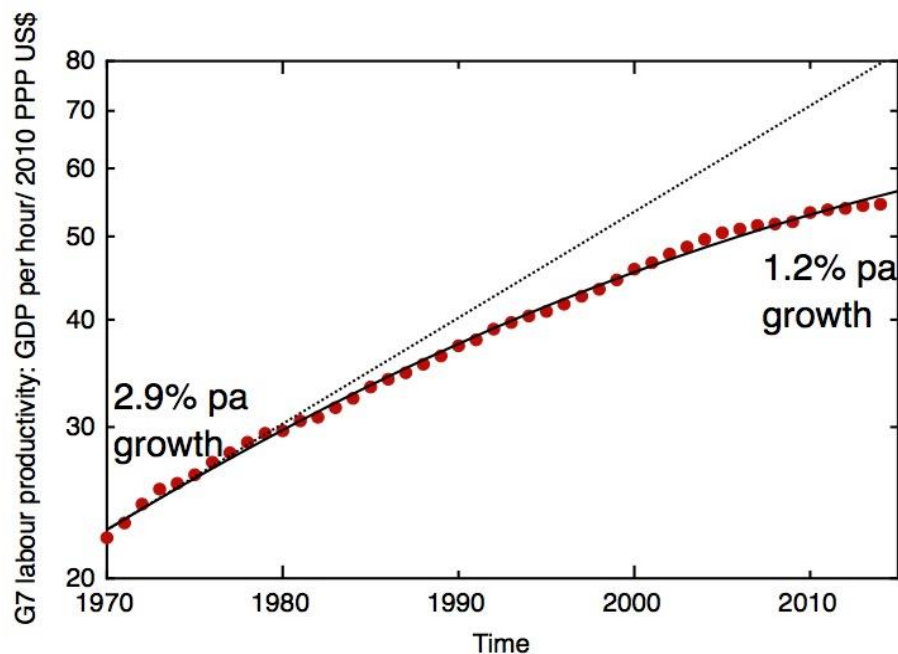


Figure 2. Labour productivity across the G7 group of nations – GDP per hour worked, currencies converted at purchasing power parity and expressed as constant 2010 US\$. The fit (solid line) is a logistic function, corresponding to an annual growth rate of 2.9% in 1970, dropping to 1.2% in 2014. OECD data.

Figure 3 shows the evolution of labour productivity in a few developed countries as expressed as a fraction of this G7 average. Both at the beginning of the period, in 1970, and at the present day, the world's productivity leader, the country at the

technology frontier, was the USA. But the intervening period saw a long relative decline through the 1970s and 80s for the USA, and a less dramatic recovery. This is set in a broader historical context in Robert Gordon's book *The Rise and Fall of American Growth*.³

The mirror image of this performance is shown by France and Germany, whose labour productivity performances have marched in step. France and Germany's relative improvement in productivity performance took them ahead of the USA on this measure in the early 1990s, but they have slipped back slightly in the last decade. Italy, however, has seen a dramatic change, beginning the period showing the same improvement as France and Germany, but then enduring a long decline, to end up with a productivity performance as poor as the UK's.

The UK has been a persistent productivity laggard. Its low point was reached in 1975, when its productivity fell to 17% below the G7 average. After a bumpy performance in the 1980s, there was a slow improvement in the 1990s and 2000s, but much of this ground was lost in the financial crisis of 2008, leaving UK productivity around 13% below the G7 average, and 24% below the world's productivity leader, the USA.

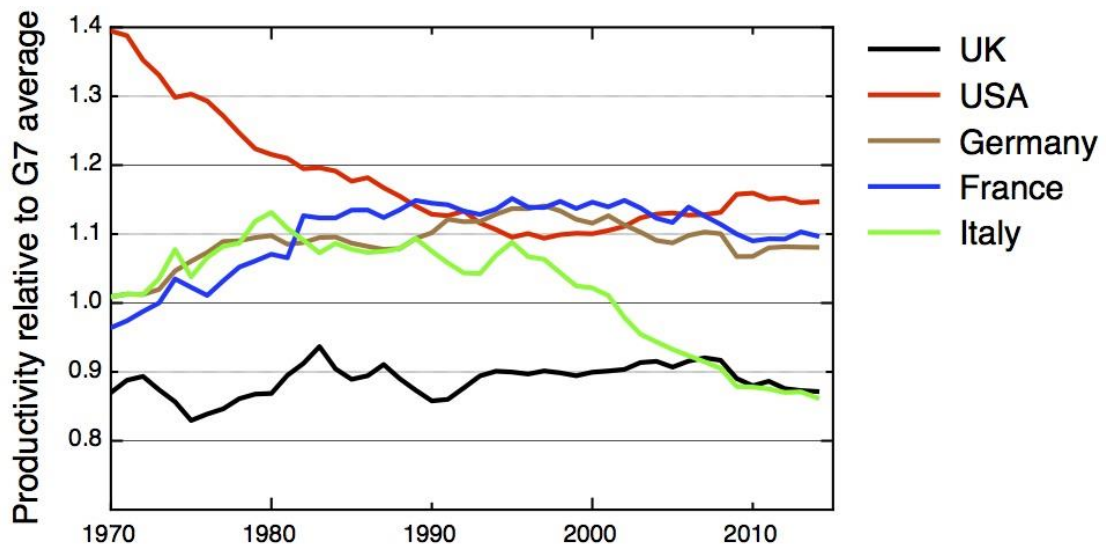


Figure 3. Labour productivity relative to the G7 average. OECD data.

The UK, then, shares the general slow-down in productivity growth in the developed world over the last forty years. But, in addition, it has two specific problems of its own – a persistent productivity gap with other countries on the technology frontier, particularly the USA, France and Germany, and the more recent, particularly abrupt, halt in productivity growth after the financial crisis. By 2015, the productivity shortfall between what we would have expected on the basis of the pre-crisis trend and current performance had opened up to 17%. This is a once-in-a-lifetime event; if we cannot work out why this happened and reverse it, the political and economic consequences will be serious.

Why productivity matters

Fundamentally, rising living standards and rising productivity are directly linked. Average wages in the long run should rise in proportion to rising labour productivity, unless there is a substantial change in the division of returns between capital and labour. In fact, there has been a decline in labour's share in the UK since the financial crisis, from around 58% to 53%,⁴ which has further exacerbated the effect of the productivity slow-down on the living standards of wage-earners.

Overall economic growth can only come from a combination of growth in productivity and growth in number of hours worked. In the UK in the last five years, such economic growth as we have seen has largely arisen from employment growth, much of that amongst recent immigrants. The government needs there to be significant GDP growth over its term of office in order to bring public finances back into balance; since much further expansion of employment growth is unlikely, a recovery in productivity growth is essential if the government is to meet its deficit reduction targets.

The official economic forecasts that underpin the government's borrowing projections have, since the financial crisis, assumed that the recent productivity stagnation is a blip from which we can expect to recover through the natural self-righting tendencies of the economy.

The timing of this putative recovery in productivity growth remains in doubt. The forecasts of the Office of Budgetary Responsibility have been consistently over-optimistic and premature in their assessment of the timing of a recovery in productivity growth, as Figure 4 shows. Indeed, the slippage of the predicted productivity recovery that took place between the Office of Budgetary Responsibility's November 2015 and March 2016 forecasts was the dominant factor in the downgrade in fiscal prospects reported in the March 2016 budget.⁵

But even this, most recent, downgraded prediction assumes that the rate of productivity growth will, if belatedly, return to a long-term average of a little more than 2% a year. But can we count on the assumption that the long-term rate of productivity growth remains unchanged?

Not necessarily: for example, some recent modelling that takes into account structural changes in the UK economy comes to the pessimistic conclusion that the new stable long-term average rate of productivity growth may now be closer to 1.4%.⁶ But one should note that even this figure would represent an improvement on the trend of recent years. Average productivity growth since 2009 has been about 0.6% a year, while the performance since 2011 has been even lower at around 0.3% a year.

If these much lower rates of productivity growth do persist, the implications will be serious – not only will the government's fiscal position be much worse than it currently assumes, but wages and living standards more generally will continue to stagnate into the next decade.

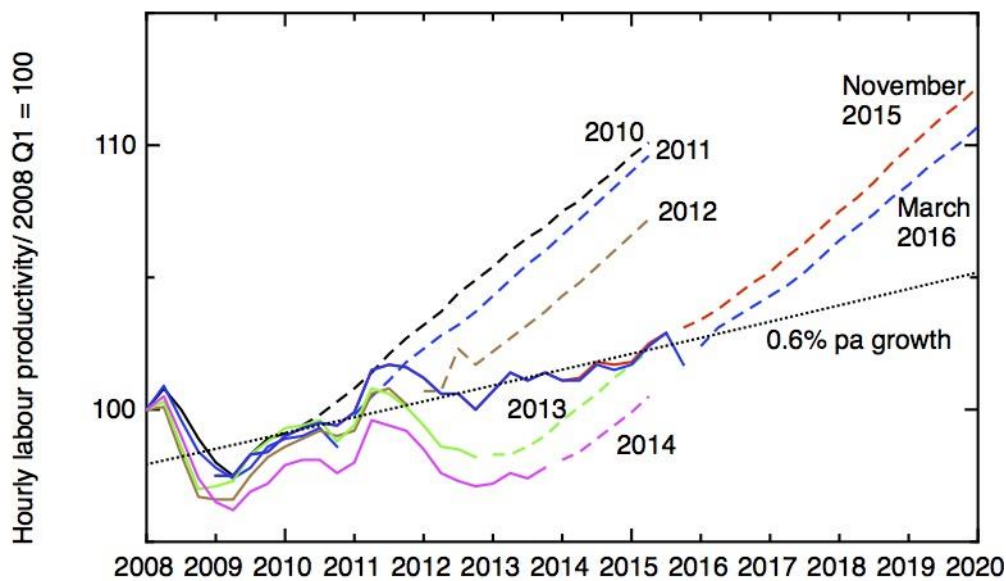


Figure 4. Labour productivity according to the successive Office of Budgetary Responsibility's Economic and Fiscal Assessments for the years indicated, showing estimates of productivity up to the time of publication of each report (solid lines), and predictions for the future (dotted lines). The dotted line is best fit to the post 2009 trend, representing 0.6% annual growth. Data for 2010-2014 from the October 2015 OBR Forecast Evaluation Report⁷ for 2015 and 2016 from the March 2016 OBR Economic and Fiscal Outlook.⁸

It is difficult, then, to overstate the importance of the outlook for productivity growth for the economic future of the country. Will the productivity growth we enjoyed before the financial crisis return, or have we entered a 'new normal', a sustained period of productivity stagnation? To understand which is more likely, and whether there is anything policy can do to steer the outcome, we need to have some better answers about where the slowdown in productivity has come from.

The UK: weak for research and development, weak for productivity growth – what is the connection?

Economists agree that the fundamental origins of productivity growth are to be found in innovation, both technological and organisational. One key measure of the resources devoted to technological innovation is the R&D intensity of the economy, so it is natural to ask whether the current slowdown in productivity is connected to the UK's long-term record of lower spending on R&D (both public and private sector) compared to other developed economies.

The data for the research intensities of a number of developed and developing economies is shown in Figure 5. The UK is close to the bottom of the league for its R&D intensity. But it does need to be stressed that the correlation between productivity growth and research and development is not straightforward – productivity growth varies across different sectors of the economy, and can be affected by different factors such as the degree of capital investment. We need a finer-grained analysis to understand the links.

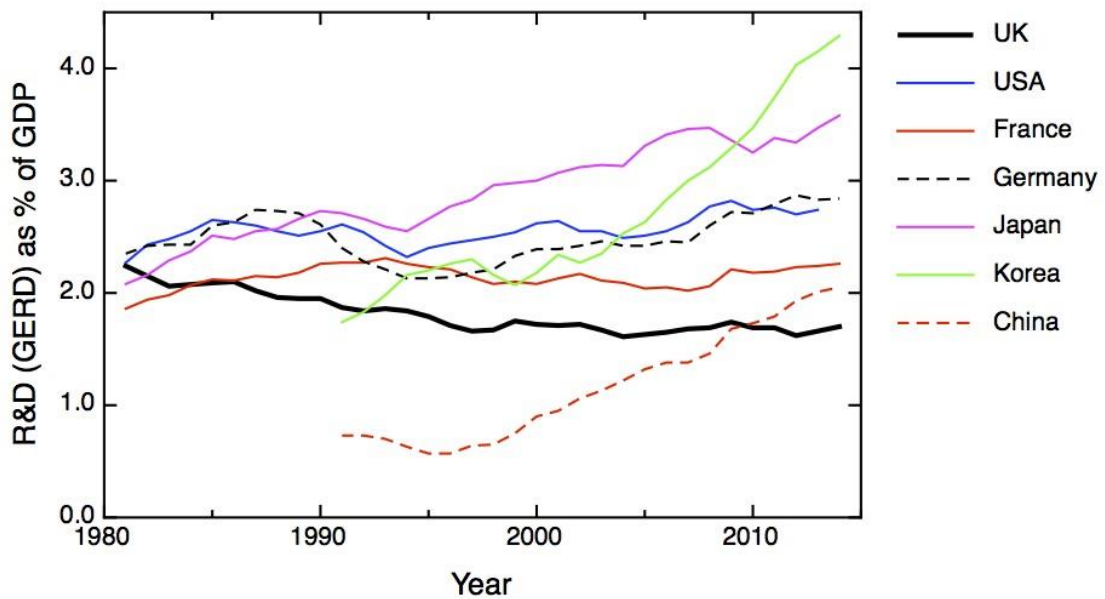


Figure 5. Research intensity of selected countries, expressed as gross expenditure on research and development as a percentage of GDP. Data: OECD main science and technology indicators, January 2016.

Analysing the UK's productivity slow-down

There are many theories of why the UK's productivity growth has stalled, including the UK's weak R&D record, a lack of competitiveness in the economy and insufficient deregulation. But it would be surprising if such a striking occurrence had just a single cause, so a more careful analysis should help us not just by ruling possible causes in or out, but by ascribing different weights to multiple causes.

A better analysis needs both to consider what we mean by productivity and its different causes in more detail, and to look at the economy on a finer scale, looking both at the productivity performance of different sectors and the balance in the economy between those different sectors.

The discipline of 'Growth Economics' conventionally considers economic growth to arrive from some combination of more labour – simply working more hours; more capital expenditure – buying more machines to do the work; and learning how to do things better. It is this collective learning how to extract more value from the same amount of input of labour and capital that growth economists call 'innovation' and measure in a quantity called 'total factor productivity' – TFP.

One explanation for a fall in productivity could be a shift in the balance between labour and capital. We normally expect, as the economy grows, for processes to be increasingly automated, so rather than having men with shovels dig ditches we buy more mechanical diggers – this process is called 'capital deepening'. We can imagine the opposite happening – if wages fell, and labour were to become cheap compared to capital, then it might not be worth the expense to buy more machines. In this case, labour might be substituted for capital, in a process of 'capital shallow-

ing'. The strong rise in total employment since the financial crisis, associated with a fall in real wages, is suggestive of this phenomenon.⁹

We also need to look at the different sectors in the economy – some sectors have naturally high productivity, others naturally are lower. We should be careful in thinking about this to distinguish between the absolute level of productivity in a sector from its rate of productivity growth (or shrinkage). For example, to anticipate some conclusions, with the development of North Sea oil and gas the UK economy grew an oil and gas sector that, for a while, had a much higher productivity than the sectors of the economy it squeezed out. This sectoral change in the UK economy resulted in an increase in the overall productivity in the economy. However, with the exhaustion of the more easily worked fields productivity in the oil and gas sector would decline, dragging down the overall economy with it.

A detailed analysis of recent productivity performance, that decomposes these different factors, has been carried out by Goodridge, Haskel and Wallis.¹⁰ This seems to dispose of some popular theories for recent productivity weakness; evidence for capital shallowing, if any, seems weak, while shifts in the sectoral balance of the economy actually seem to have been working to increase productivity rather than decrease it.

Their conclusion is that our productivity problem is a problem of total factor productivity – and thus a problem of innovation, using that term in the economists' most general sense. There are two special sectors that, between them, account for a third of our problem. One of these is oil and gas, where declines in total factor productivity reflect the problems of a resource moving towards exhaustion, where increasing amounts of labour and capital are required to extract what oil and gas remains. The other is financial services, whose circumstances were changed in the aftermath of the financial crisis. But total factor productivity is a problem in virtually all sectors, and this must reflect failings of some form in our ability to innovate.

Two ongoing headwinds for UK productivity – the decline of North Sea oil and the end of the banking bubble

The importance of the decline of North Sea oil and gas should not be a surprise to anyone. Offshore oil and gas production ramped up in the 1980s and 1990s, making the UK a significant world producer. As the plot below shows, oil production peaked in 1999; gas production peaked one year later, in 2000. Since then, there has been a steep decline in production, which is projected to continue more gently into the foreseeable future (this trajectory will be strongly influenced by oil prices, and is likely to be steeper the longer low oil prices persist¹¹).

When large quantities of oil, that could be sold for high prices, were being produced by a relatively small number of workers, this produced a substantial boost to the UK's productivity. Declining North Sea oil produces two direct effects on overall productivity. Firstly, as the oil gets more difficult to extract, less output is created for a given input, so the productivity of the sector is reduced. Secondly, as the sector reduces in size, because its productivity remains high relative to other sectors of the economy, the economy's overall productivity drops.

Indirect effects are more difficult to identify, but it is plausible to argue that North Sea oil contributed to what economists call 'Dutch Disease', in which the oil effect leads to a high value of the currency, making other tradable sectors, such as manufacturing, less competitive.

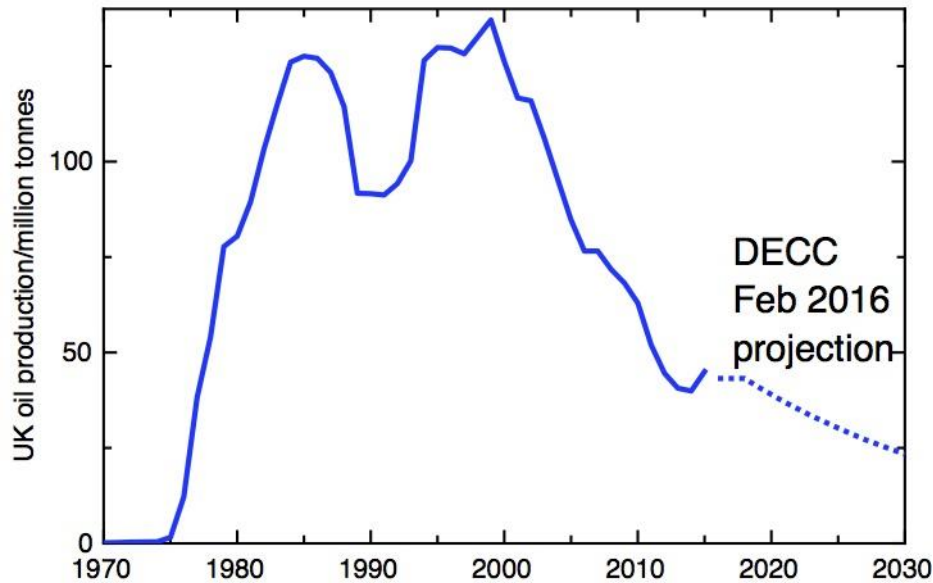


Figure 6. Actual and projected production of oil in the UK mainland and continental shelf. Data: DUKES 2015¹² and projection: DECC Oil and Gas Projections.¹³

Figure 7 shows labour productivity in the finance and insurance sector. Just as North Sea oil was peaking in 2000, productivity in finance industry went into a new phase of fast growth. This growth slowed in 2006, went into a post-crisis reverse in 2009, and is still declining. Of course, what is meant by output in the finance sector is less clear than it is for oil and gas, where one can measure the barrels that come out of the ground.

What the financial crisis revealed was that some of the profits taken before the crisis represented the upside from excessive risk-taking, and when those gambles turned sour the tax-payer took on the losses. In effect, pre-crisis profits were overstated because the banks were benefitting from an implicit insurance against failure, whose premiums were being paid by the state. There are different estimates of the value of this state subsidy, reviewed in this Bank of England paper,¹⁴ but even conservative estimates amount to £10s of billions.

Our previous dependence on the financial sector also is likely to have had damaging indirect effects on our long-term economic growth prospects, as discussed in a recent Bank of International Settlements working paper.¹⁵ I discussed the role of excessive financialisation in suppressing private sector investment in research and development in my earlier paper, *The UK's innovation deficit and how to repair it*.¹⁶ Modern economies need strong and functional financial services sectors, to distribute capital to where it can most productively be used, to re-distribute risk according to different people's appetites and requirements, and to match people's needs to defer some of their consumption – i.e. to create reliable and cost-effective savings and pensions vehicles. The danger, though, is that over-strong finance sec-

tors can evolve into what Acemoglu and Robinson (in their book *Why Nations Fail: The Origins of Power, Prosperity and Poverty*¹⁷) call 'extractive institutions', extracting rents from more productive parts of the economy by exerting their political power. The evidence is not overwhelming that the UK's financial services sector has been particularly effective at fulfilling the former set of useful functions, and parts of it have arguably been slipping in the latter direction.

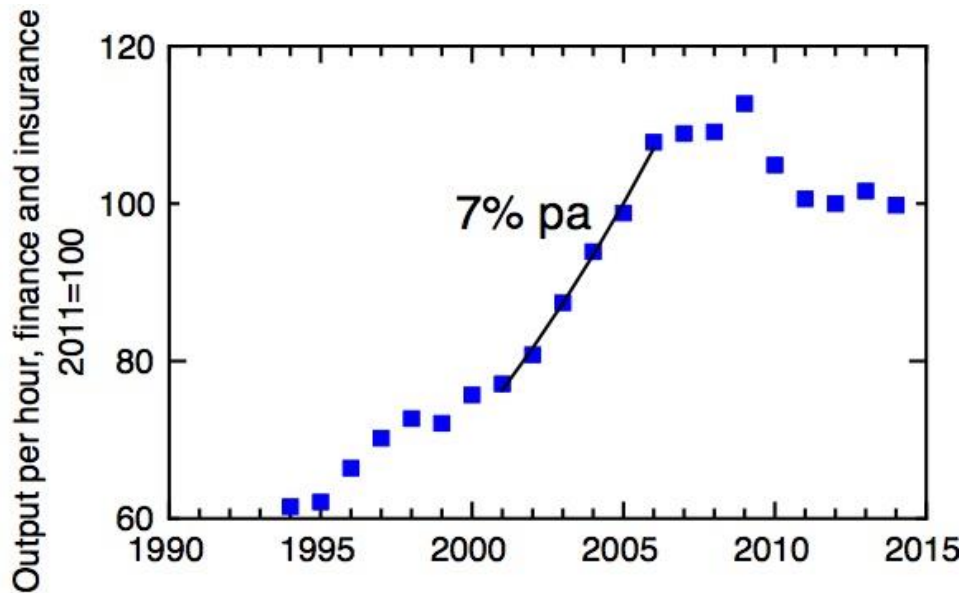


Figure 7. Labour productivity in the UK's finance and insurance sector. The period between 2001 and 2006 corresponds to an annual growth rate of 7%. ONS data.¹⁸

Over the past few decades, the UK's economic prosperity has relied on North Sea oil and the rapid growth of the financial services industry. Neither of these sources of wealth is going to come back. We do see enthusiasm from the government for the prospects for extracting onshore gas through the new technology of hydraulic fracturing (fracking), and it is tempting to see this enthusiasm as an expression of nostalgia for the North Sea oil boom. This is not the place to discuss the pros and cons of fracking, but it is important to note that judged internationally, the UK's shale gas reserves are unexceptional.¹⁹ Even in the USA, where the environment and infrastructure for fracking is greatly superior to the UK, the economics of shale gas and tight oil are difficult with oil less than US\$50 a barrel.²⁰ So, even leaving aside political and environment considerations, these economic issues make it difficult to see a shale gas industry developing in the UK in the near future, at least on scale to make a serious economic impact.

Likewise, the boom in financial services that seemed such a driver of productivity growth before the 2008 financial crisis should not be allowed to recur, now that we know the enormous cost of that crisis. The financial services sector in the future needs to be more highly regulated, to reduce the risk and mitigate the consequences of future financial crises, and as a result the sector will be less profitable and smaller. New technology offers new possibilities in the financial services sector, and there is excitement about so-called 'fintech'.²¹ But the lesson of the financial crisis is that, in finance as in other sectors, not all innovation is positive. Enthusiasm for 'fintech' needs to be tempered by searching questions about whether

these innovations bring about genuine utility to consumers and society at large, or whether they rely on regulatory arbitrage for their apparent profitability.

Given that both our oil and gas boom and our financial services bubble have proved to be unsustainable, in the years to come we will have to find other sources of growth. To restore the economy's productivity growth to levels we have come to expect, we are not just going to have to restore productivity growth in the other sectors of the economy to pre-crisis levels; we will have to increase it yet further to compensate for the continuing drag from oil and gas and financial services.

Productivity leaders and productivity laggards – firm-level heterogeneity of productivity within sectors

Discussing productivity growth at the level of entire sectors disguises the fact that there can be a very strong variation in the productivity achieved by different firms operating in the same sector. An overall change in the productivity of a sector could be caused, at one extreme, by the productivity within each firm in that sector changing or, at the other extreme, by a change in the balance between high-productivity and low-productivity firms. It has been suggested that the aftermath of the financial crisis led to a change in the dynamics of firm entry and exit. A credit crisis might mean that high-productivity, fast-growing firms cannot get the funding to expand, while it may be that an environment of greater bank forbearance of non-performing debts might mean that low-productivity firms are kept alive longer than would be the case in normal circumstances. But a detailed study of this issue concluded that the recent productivity weakness was largely within firms, and much less an issue of a change of the balance between high-productivity and low-productivity firms.²²

Given the wide level of heterogeneity in the productivity performance of individual firms within a sector, the question of how productivity-enhancing innovations diffuse from high- to low-productivity firms becomes important. An OECD analysis at the international level distinguishes between firms on the global productivity frontier, for which productivity growth has remained robust, and the rest, which have performed less well. The gap between global leaders and the productivity laggards has widened, for reasons that are not clear.²³

The OECD analysis argues that productivity-enhancing innovations diffuse first from the firms at the global productivity frontier to national leaders in each country, and only then to the productivity laggards. This suggests that we need to ask how many firms at the global productivity frontier the UK has in each sector, how effectively the UK's national leaders catch up with the technology frontier, and the degree to which the laggards learn from the national leaders. We expect a correlation between the degree to which firms are close to the technology frontier and their participation in R&D – at least in sectors such as manufacturing and ICT – suggests that this may be another channel by which the UK's relative weakness in business R&D can contribute to its overall poor productivity performance.

Quantifying the productivity benefits of research and development

The UK's productivity problem is an innovation problem. This conclusion follows from the analysis of Goodridge, Haskel and Wallis, at least if one equates the economist's construction of total factor productivity with innovation.²⁴ This needs some qualification, because when economists talk about innovation in this context they mean anything that allows one to produce more economic output with the same inputs of labour and capital. So this can result from the development of new high-value products or new, better processes to make existing products. Such developments are often, but not always, the result of formal research and development.

But there are many other types of innovation. People continually work out better ways of doing things, either as a result of formal training or simply by learning from experience, they act on suggestions from users, they copy better practises from competitors, they see new technologies in action in other sectors and apply them in their own, they work out more effective ways of organising and distributing their work; all these lead to total factor productivity growth and count as innovation in this sense.

There has been a tendency to underplay the importance of formal research and development in recent thinking about innovation, particularly in the UK. This has arisen partly because the manufacturing and ICT sectors, in which R&D has always been more prominent, have declined in importance relative to service sectors. In the period up to the financial crisis, it was noticed that the UK's productivity seemed to be growing very healthily, despite lower R&D spending than in competitor nations, which seemed to suggest that R&D had become less important for innovation than it had been before. The poor performance of the UK economy since the crisis has made the paradox of apparently strong productivity growth with weak R&D less puzzling.

R&D remains important because it provides an organised and systematic way of bringing together teams of talented people with capital-intensive equipment, to harness the new opportunities arising from the advance of science in the focused pursuit of new products and processes. R&D was itself an important social innovation, whose development was just as important in driving the great technological saltation that took place in the late 19th and early 20th centuries (sometimes called the 'second industrial revolution') as the underpinning scientific discoveries in chemistry, electricity and electronics had been.²⁵

It is true, however, that it has been more difficult to apply these methodologies to the service industries, and this no doubt has contributed to the weaker productivity growth that we see in those sectors. There are high hopes that new ICT technology will change this, but it is difficult to see evidence yet that this is showing up in the productivity statistics. It may be that we are still yet to develop the social innovations that will allow us to fully benefit from the new technologies in services.

The direct contribution of R&D spending, both public and private, on productivity and economic growth has been estimated in another recent paper from Goodridge, Haskel, Hughes and Wallis.²⁶ The headline results of this econometric study are that the rate of return on public sector R&D is about 20%, and that a 10% increase

in public R&D spend would result in an increase of private sector total factor productivity from 1.46% to 1.49% pa.

To put this in perspective, the increase in public sector R&D spending (0.48% of GDP in the UK, 2013) that would be required to bring it up to the OECD average (0.67%) would be about 40%!

This estimate of the return on public sector R&D is likely to be an underestimate since the extent to which the private-sector economy can benefit from public R&D – its absorptive capacity – depends on the structure of the economy and the amount of private sector R&D being carried out. An economy like Germany's, with a larger manufacturing sector than the UK, gains even greater benefits from public sector R&D.

It is known from many studies that one effect of public sector R&D is to 'crowd in' further private sector R&D. Countries with a higher intensity of public sector R&D tend to have a higher intensity of private sector R&D, as shown in Figure 6. A recent study commissioned by the Government concludes that an extra £1 of public funding of R&D in the UK would give rise to an increase in additional private funding of R&D of between £1.13 and £1.60,²⁷ while a more focused study on the relationship between government and charity spending on biomedical research and private pharmaceutical R&D in the UK concluded that £1 public /charity R&D expenditure gives rise to £0.83–£1.07 extra private R&D.²⁸

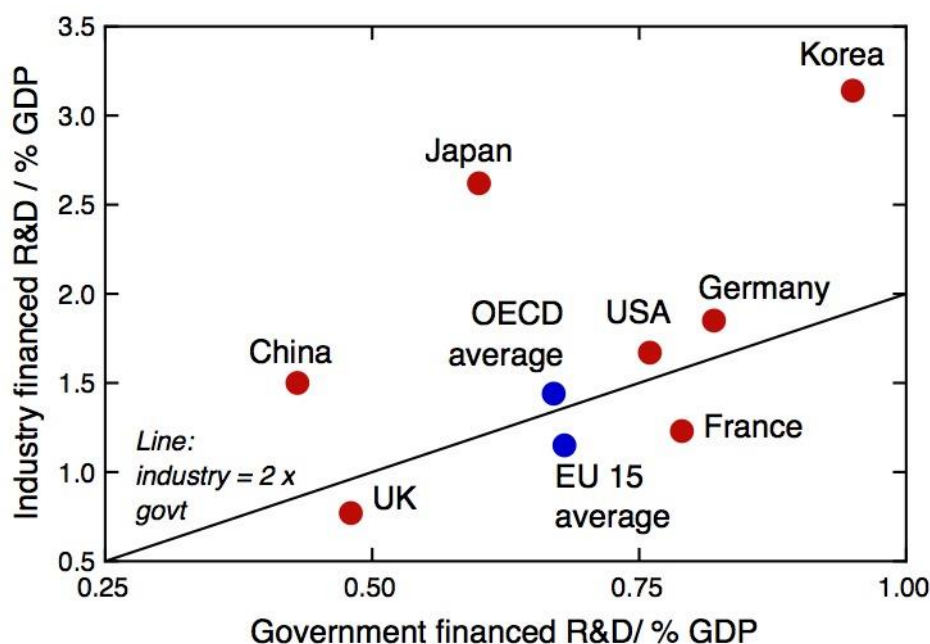


Figure 8. Government financed R&D and industry financed R&D for selected countries, expressed as % GDP. 2013 data from OECD Main Science and Technology Indicators, January 2016 release.

An increase in private -ector R&D has two effects – the private-sector R&D directly raises the productivity in the industries concerned, but it has the indirect effect of further raising the absorptive capacity of the economy and leading to further productivity gains.

The importance of productivity growth, and what can be done to restore it

Ever since the financial crisis, there has been an assumption that productivity growth will soon return to its 'normal', pre-crisis trend of 2.2 or 2.3% a year. Eight years on, that assumption looks less and less plausible; instead, we have to face the growing likelihood that we are now living in a 'new normal' of much lower productivity growth. If so, this will not only disrupt the government's fiscal plans, but also put a damper on the likely trajectory of wages and living standards over the next decade and beyond.

What could have changed to cause this change in national fortunes? The end of a boom in oil and gas and the bursting of a bubble in financial services have been significant factors, and those previous supports to our national prosperity are not coming back. But what the removal of these props has revealed is a wider problem of innovation across a number of sectors of the economy.

There is a suite of measures that conventional wisdom prescribes for improving productivity. Many of these are summarised in the phrase 'structural reform' - for example, the promotion of competition through deregulation of labour and product markets. Other measures include the improvement of infrastructure, whether that is fast broadband, roads, or trains and other public transport, more investment in skills, and more support for innovation.

Because many of these remedies have already been tried at different times in different countries, we are beginning to be in a position to assess whether they actually work. One econometric study of the influence of various structural reforms on total factor productivity growth was recently reported by the IMF.²⁹ This concluded that labour market deregulation actually has a negative effect on productivity; product-market deregulation has a positive effect in the long term, though its short-term effects can be negative, especially in ICT. Improving labour skills is particularly positive for productivity in manufacturing and ICT, while infrastructure, ICT capital, and research and development have overall positive effects on productivity growth in both the short and long term.

Of course, the fact that there is a widespread economic consensus about the positive benefits of such measures does not always translate into a political will to put them in action, at least on a material scale. Nor is it always obvious what the most effective way of addressing each of these issues. Innovation is a case in point: everyone agrees that there should be more of it, but there is less clarity about how this is to be achieved.

One area of focus should be the UK's very weak record in R&D, and the extent to which this undermines its innovation performance more generally. As we have seen, the UK has seen a long-term decline in R&D intensity over the last few decades, and is now one of the least research intensive of the major economies, as I discussed in my earlier SPERI paper.³⁰ Policy makers have been aware of this for some time, but the apparently healthy pre-crash economy led to complacency that one could run an innovative economy at the technology frontier without R&D. The current productivity slowdown is strong evidence that this complacency is no longer sustainable.

The majority of R&D is carried out by the private sector, and the UK weakness in business R&D is likely to be a key factor in low productivity growth in R&D intensive sectors such as ICT and manufacturing. But public-sector R&D is also important for private-sector productivity, both through providing a stock of new knowledge and skilled people that the private sector can use, and indirectly by encouraging the private sector to do more R&D on its account, reflecting the well-established effect by which public-sector R&D 'crowds in' private-sector R&D. The connection between public-sector R&D, the overall research intensity of the economy, and productivity growth is direct. Haskel's econometric analysis makes it clear that an increase in R&D intensity towards OECD average would have a material positive effect on productivity growth.³¹

But reversing the situation is not going to be done without some careful thought about how best to strengthen our overall innovation system. This needs explicit and separate consideration of business R&D, both in existing companies and in fast-growing start-ups, applied science and technology in support of the strategic goals of the state, and the more long-term discovery science done in universities and research institutes.

Science and innovation policy for the last fifteen years has been dominated by supply-side measures – maintaining a strong research base in universities and research institutes ensuring a supply of skilled people, and through instruments like the R&D tax credit and the patent box providing general incentives to companies to carry out R&D. These have not been sufficient to arrest the decline in the R&D intensity of the UK's economy.

These supply-side measures are important (and international comparisons suggest that they are sub-scale), but they need to be matched by actions to address the demand side of innovation. Some serious and focused efforts have to be made to develop the new technologies we know we need. There is a wide consensus about what some of those needs are in a general sense. We need, for example, to develop low-carbon energy at a cost that is competitive, without subsidy, with fossil fuels, and we need to create the healthcare technologies and social innovations that will allow us to care for an ageing population affordably.

This will need a much more explicit recognition from government that to meet its strategic goals it will need to get much more closely involved in innovation at the downstream, delivery end. We have seen the consequences of hands-off approach to technology development and procurement in the low-carbon energy sector. Here the expectation that scalable new technologies will spontaneously emerge, and pseudo-market mechanisms can be used to discriminate between them to achieve the most cost-effective solution, has been tested to destruction in the nuclear-new-build programme, now a decade late and with its costs escalating.

These new technologies will need to be procured by the state, but largely delivered at scale by the private sector. This should be part of an explicit strategy to rebuild private-sector R&D capacity, creating more global productivity leaders, who can help spread productivity enhancing new technology into lower-productivity firms in their sectors, for example through their own supply chains. The development of these technologies need to be carried out in a way that is responsive to the needs of customers and users. Particularly in areas such as health and social care, there will be a need for social and organisational practices to co-develop with the new

technologies. If possible and appropriate, this technology development should be carried out as part of international collaborations.

It is clear that the structures of government currently do not have the capacity or the cultures to drive this more active procurement of technology. This is paradoxical at one level, in that it is departments like the Department of Energy and Climate Change and the Department of Health that will reap the consequences of a lack of innovation, in the shape of escalating costs in health and social care and the consequences of the potential failure to meet long-term goals for energy decarbonisation. But the pressures of immediate cost-cutting, together with dysfunctional incentives for innovation in the current pseudo-markets in health and energy and a conviction that, given the right market incentives, appropriate new technology will 'emerge', have led to a situation where departments seem largely impotent to act.

Looming large over all other government departments is HM Treasury – to which is attributed, by some observers, a tendency to exert excessive central control and a bias to short-termism, to the detriment of the longer-term approach which is essential for innovation. One response is to call for the break-up of the department, creating a new Ministry of Growth.³² Alternatively, a more pragmatic response might be to recognise the continuing centrality to government of a powerful Treasury, but to reform it and redefine it as the state's economics ministry, with an explicit responsibility to develop and be the steward of the nation's model for economic growth.³³

The government is faced with a continuing stagnation in productivity growth, whose serious economic, fiscal and political consequences are becoming more and more obvious. It now needs to take much more seriously its responsibilities to coordinate and promote technological growth. The supply-side innovation policies that have been supported by a political consensus for several decades should certainly be continued and stepped up. But there needs to be a recognition that, by themselves, these have not been sufficient, and that these measures need to be supplemented by a much more active approach to driving and procuring the new technologies that are required to meet the strategic goals of the state.

In addition to these positive policies to promote technological innovation, we need to address those factors that impede it. These include a dysfunctional and over-large financial services sector, capital markets biased to the short term³⁴ and an incentive system for managers of public companies that work against long-term investment.³⁵ We need a government that supports a developmental state, and a new political economy of technological innovation.

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