The Entrepreneurial State

Book

"The state has not just fixed markets, but actively created them..."

THE ENTREPRENEURIAL STATE

Mariana Mazzucato

DEMOS

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All opinions, and errors, remain my own.

Mariana Mazzucato
June 2011

Preface

Innovation policy in Britain has become tired and is in need of refreshing. This pamphlet by Mariana Mazzucato, currently Professor in the Economics of Innovation at the Open University, and soon to be the new RM Phillips Chair in Science and Technology Policy at the University of Sussex, is therefore a timely and important contribution to what is a necessary debate. Over the last two decades, if not longer, the British Government has defined its role in economic policy as working to ensure a macroeconomy and infrastructure that is conducive to private sector activity, only intervening where there is a supposed market failure; beyond that it leaves the job of wealth creation to the market. Up to a point, that works. But, as this pamphlet shows, opportunities are being missed if recent developments in innovation literature, economic theory in general, and experience from elsewhere in the world are not also drawn on in setting UK policy.

The first insight, described in chapter 3, is that networks and connections really matter. This is not a surprise to those involved in the growing discipline of complexity and behavioural economics, but it is a fact that does not yet lie at the heart of UK economic policy. We understand that there is value in a cluster, and we support the building of business incubation units in science parks, but we do not fully accept the responsibility of government continually to foster horizontal links between existing institutions in order to create a flat structured national system of innovation in every discipline.

The second insight is that even where the network exists, it takes a nimble, interventionist, knowledge-hungry state to catalyse them into action. If it is in the public interest for innovation to occur, there is a role for the public sector to require it to happen, rather than sitting back and hoping it will happen of its own accord provided the conditions are right. Countries playing economic catch-up are able to do this relatively easily by having government strategies that copy what has happened elsewhere in the world. At the frontiers of knowledge, the role of government is harder to comprehend. This pamphlet draws on the experience of the USA in particular to show that innovation is far more likely to happen when it is commissioned via a multitude of contracts for particular advances or technological solutions, rather than by — for example — providing tax credits for general research and development, or badgering the banks to lend more to certain parts of the economy. This is not so much nudge as necessity. And scale matters.

The political danger is that in an era where governments — and to a degree the public — believe the state has got too big, any talk of an interventionist approach in growth policy will be intellectually filed under the same heading as the failed policies of the 1970s. But this is not about hand-outs to unproductive national champions, nor is it Keynesian demand management. It is about looking at what works and making it work for the UK.

The complexity economist W Brian Arthur in his recent book *The Nature of Technology* talks about technology in a functional way as a means to a purpose, and about innovation as the combination and Darwinian-style evolution of complementary technologies.[1] Radical change occurs when a new underlying principle is invoked in order to solve the technological problem being considered when more conventional solutions have failed.

We hope that this pamphlet will, in its own way, provoke a radical change in the understanding of the role that government can play in economic policy. We hope to spark a conversation about what the state can do to use its power to specify the problems it wishes to solve through technological advance and innovation, thereby ensuring that those advances are able to take place.

In summary, we say we want a more entrepreneurial economy. That doesn't necessarily require the state to withdraw, but to lead.

Kitty Ussher
Director of Demos
June 2011

Introduction and summary

Across the globe we are hearing that the state has to be cut back in order to foster a post-crisis recovery, unleashing the power of entrepreneurship and innovation in the private sector. This feeds a perceived contrast that is repeatedly drawn by the media, business and libertarian politicians of a dynamic, innovative, competitive private sector versus a sluggish, bureaucratic, inertial, 'meddling' public sector. So much so that it is virtually accepted by the public as a 'common sense' truth.

For example, in his budget speech of June 2010, a month after taking office, the Chancellor, George Osborne, stated that the public sector was 'crowding out' the private sector, providing an additional justification beyond the need to reduce the deficit, for a relative contraction of the state. Both in the documentation that supported that emergency budget, and subsequently, the Coalition Government has repeatedly called for a more 'balanced' economy, with private activity taking up a greater share of the total than has previously been the case. The Prime Minister, David Cameron, adopted a more polemic tone in a speech given to the Cardiff Spring Forum in March 2011 when he promised to take on the 'enemies of enterprise' working in government, which he defined as the 'bureaucrats in government departments'.[2] This is a rhetoric that fits with the Government's broader theme of the Big Society, where responsibility for the delivery of public services is shifted away from the state to individuals operating either on their own or by coming together through the third sector.

And it is not a view that is unique to the UK Government. *The Economist,* which often refers to government as a Hobbesian Leviathan,[3] recently argued that government should take the back seat and focus on creating freer markets and creating the right conditions for new ideas to prosper, rather than taking a more activist approach.[4] The established business lobby groups have long argued for freedom from the long arm of the state, which they see as stifling their ability to succeed through the imposition of employee rights, tax and regulation. The right-wing Adam Smith Institute argues that the number of regulators in the UK should be reduced to enable the British economy to 'experience a burst of innovation and growth'.[5] In the USA, supporters of the Tea Party movement are united by a desire to limit state budgets and promote free markets.

While business as a whole may not see the virtues of anything that does not have a clear and positive impact on its bottom line, and nor arguably should it, there is a danger when a general desire to reduce the size of the state translates into weak and non-ambitious economic policy. When that happens, we are all losers: policy is not as effective as it could be and the potential to create greater prosperity is not fulfilled.

This pamphlet argues that there is a real danger of that happening in the field of innovation policy, greatly limiting its impact on economic growth. The view of the current government—shared by its predecessor—is that the role of the state in spurring innovation is simply to provide the 'conditions for innovation to flourish'.[6] The UK Government states that if it invests in skills and a strong science base, ensures a strong legal framework within an amenable macroeconomy, and supports entrepreneurial clusters, then the market will do the rest through the incentive of the profit motive.

The evidence presented in this pamphlet challenges this minimalist view of the state in the field of economic policy, arguing that a far more proactive role is required. The case that is made in these pages is that the role of the government, in the most successful economies, has gone way beyond creating the right infrastructure and setting the rules. It is a leading agent in achieving the type of innovative breakthroughs that allow companies, and economies, to grow, not just by creating the 'conditions' that enable innovation. Rather the state can proactively create strategy around a new high growth area before the potential is understood by the business community (from the internet to nanotechnology), funding the most uncertain phase of the research that the private sector is too risk-averse to engage with, seeking and commissioning further developments, and often even overseeing the commercialisation process.. In this sense it has played an important entrepreneurial role.

Of course there are plenty of examples of private sector entrepreneurial activity, from the role of young new companies in providing the dynamism behind new sectors (eg Google), to the important source of funding from private sources like venture capital. But this is the only story that is usually told. Silicon Valley and the emergence of the biotech industry are usually attributed to the geniuses behind the small high tech firms like Facebook or the plethora of small biotech companies in Boston or Cambridge in the UK. Europe's 'lag' behind the USA is often attributed to its weak venture capital sector. Examples from these high tech sectors in the USA are often used to argue why we need less state and more market: to allow Europe to produce its own Googles. But how many people know that the algorithm that led to Google's success was funded by a public sector National Science Foundation grant?[7] Or that molecular antibodies, which provided the foundation for biotechnology before venture capital moved into the sector, were discovered in public Medical Research Council (MRC) labs in the UK? Or that many of the most innovative young companies in the USA were funded not by private venture capital but by public venture capital such as through the Small Business Innovation Research (SBIR) programme?

Lessons from these experiences are important. They force the debate to go beyond the role of the state in stimulating demand, or the role of the state in 'picking winners' in industrial policy, where taxpayers' money is potentially misdirected to badly managed firms in the name of progress, distorting incentives as it goes along. Instead it is a case for a targeted, proactive, *entrepreneurial* state, able to take risks, creating a highly networked system of actors harnessing the best of the private sector for the national good over a medium- to long-term horizon. It is the state as catalyst, and lead investor, sparking the initial reaction in a network that will then cause knowledge to spread. The state as creator of the knowledge economy.

It cannot be called 'new' industrial policy because it is in fact what has happened, though in a 'hidden way' to prevent a backlash, over the last three decades in the development of the computer industry, the internet, the pharma–biotech industry, and many more including today's nanotech industry.[8] None of these technological revolutions would have occurred without the *leading* role of the state. It is about admitting that in many cases, it has in fact been the state, not the private sector, that has had the vision for strategic change, daring to think — against all odds — about the 'impossible', creating a new technological opportunity, making the large necessary investments, and enabling a decentralised network of actors to enable the risky research, and to allow the development and commercialisation process to occur in a dynamic way.

This pamphlet draws together recent academic literature to make new policy conclusions. In doing so it presents a very timely contribution to the debate around deficit reduction in the UK and elsewhere. And in passing, it confronts head-on some issues that have come to be taken for granted by mainstream policy makers, such as the usefulness of data on patenting and R&D expenditure as proxies for wealth-creating innovation. The part played by the small firm in creating growth is also put under scrutiny as is the role of venture capital.

This is not a pamphlet about innovation policy. Many themes on that general topic are missing here: the skills gap, diffusion of existing innovations, procurement and deployment. It is about the entrepreneurial role that the state has played in different innovation contexts, leading rather than following. Thinking out of the box, defining new radical technologies and the associated eras (the knowledge economy), rather than just reacting to them. Understanding this lesson forces us to rethink what the state brings to the ecology of the business-government partnerships so discussed today.

The main task is to unpack the role of the state in fostering radical growth-enhancing innovations, and so to make recommendations that would not only improve the effectiveness of economic policy but also ensure that the limited taxpayers' money that is available is more effectively spent. The fear is that without understanding the proactive role required of government for an effective economic policy, the UK economy will fail to achieve its potential at precisely the time when economic dynamism is most necessary.

The report is structured as follows. Chapter 1 sets the scene by summarising the academic framework regarding the debate around growth; whereas a generation ago, technological advance was seen as something that was externally given, there is now extensive literature to show that actually it is the rate, and direction, of innovation that drives the ability for economies to grow. This provides the justification for increased focus on the role that government can play to facilitate precisely that innovation, while at the same time exploding some of the myths that abound in Westminster, the European Commission and Washington about what actually drives innovation and growth. Specifically, it draws on recent academic literature to show that targeting resources towards R&D spend, patenting or small firms in isolation misses the point and that similarly waiting for venture capital to do all the heavy lifting is likely to be futile.

Chapter 2 describes the importance of the government's role in investing where the private sector will not, in the most uncertain risky areas. But rather than understanding this through the usual lens of 'market failures', the concept of entrepreneurial risk-taking is introduced. The public sector has indeed fulfilled an important role in undertaking the most risky research, even when that research was not 'basic'. Private sector examples are provided from the pharmaceutical and biotech industries where it has been the state, not the private sector, that has created economic dynamism. Risky research is funded by the publicly funded labs (the National Institutes of Health or the MRC) while private pharma focuses on less innovative 'me too drugs' and private venture capitalists enter only once the real risk has been absorbed by the state. And yet make all the money. In industries with such long time horizons and complex technologies, it is argued that return-hungry venture capital can in fact sometimes be more damaging than helpful to the ability of the sector to produce valuable new products.

Chapter 3 argues that it is only by creating a so-called national system of innovation built on sharing knowledge that the necessary, if not sufficient, conditions start to be established. An example is drawn by comparing and contrasting the two examples of Japan and the Soviet Union. It then develops the concept of the entrepreneurial state where not only is there a fully functioning national system of innovation, but this system is catalysed by proactive, flexible, decentralised action on the part of government.

Chapter 4 examines aspects of the recent industrial policy history of the USA, and shows that despite common perceptions, the US state has been extremely proactive and entrepreneurial in the development and commercialisation of new technologies. Four examples—the Defense Advanced Research Projects Agency (DARPA), Small Business Innovation Research (SBIR), orphan drugs and recent developments in nanotechnology—are used to illustrate this point.

Chapter 5 provides some reflections that are relevant to the situation faced by the UK at the moment, with policy recommendations for the development of green technology, and technology, generally. Green technology has the potential to become the next technological revolution, but as no other technological revolution has simply been 'nudged' by the state, it is unrealistic that this one can be without the type of large scale (though decentralised) investments that have been made in the case of other important new technologies.

And finally, chapter 6 concludes with some reflections on the implications of the concept of the entrepreneurial state for the debate around fairness and distribution.

Taken together, the pamphlet paints a fuller understanding of the public sector's centrality to risk-taking and radical growth fostering technological change. It builds a very different picture of the state from that envisaged by present economic policy, which denies it any leading role in innovation and production, and that of conventional industrial policy, which unduly downplays its scope for pioneering and promoting new technologies. In contrast, it describes scenarios where the state has provided the main source of dynamism and innovation in advanced industrial economies, pointing out that the public sector has been the lead player in what is often referred to as the 'knowledge economy'—an economy driven by technological change and knowledge production and diffusion. Indeed, from the development of aviation, nuclear energy, computers, the internet, the biotechnology revolution, nanotechnology and even now in green technology, it is, and has been, the state not the private sector that has kick-started and developed the engine of growth, because of its willingness to take risk in areas where the private sector has been too risk-averse. In a policy environment where the frontiers of the state are now being deliberately rolled back, that process needs more than ever to be understood so that it can successfully be replicated. Otherwise we miss an opportunity to build greater prosperity in the future.

Recommendations

This is a summary of the main recommendations:

- Reduce government spending on direct transfers to small firms, such as small business rates relief and inheritance tax relief. This is a cost saving.
- If the Small Business Research Initiative (SBRI) is enhanced, as the government has indicated, it must be done in a way that focuses on how to get SMEs to spend money on new technologies. To do so, it will need to increase the size of the project financing that it administers (too diluted currently), and concentrate on firms that prove they will spend on innovation. This is cost neutral.
- Abandon initiatives to establish a UK patent box (a preferential tax regime for profits arising from patents), which would not increase innovation and according to the Institute for Fiscal Studies would in time lead to greater taxpayer costs. This is a cost saving.
- Review R&D tax credits with a view to ensuring that firms are held accountable for actually spending the money on innovation, and failing that, shift away from blanket R&D tax credits to free up resources towards direct commissioning of the technological advance in question. This is a potential cost saving.
- Enterprise zones, that give regulatory or taxation advantages to firms in a certain area, are a distraction as they do not cause innovation to happen that would not have taken place elsewhere. Best to use the money in other ways. This is a cost saving.
- When successful, a part of the return from investments made with significant public support should be returned to government. This is a potential cost saving.

- Use these freed-up resources to engage in a massive expansion of the Technology Strategy Board, structured in line with the model of the US DARPA to directly enable innovation (research, development and commercialisation) through a bottom-up government-directed network of agencies, in line with recommendations of the Confederation of British Industry (CBI) in 2006.[9] It also requires more transparency about funding decisions and clearer auditing of performance so that failing performance areas are cut off. This would increase expenditure.
- Adopt a more proactive interventionist approach to green technology innovation, drawing on the UK's specific strengths. This would increase expenditure.
- The time any private equity investment must be held before the gains from sale can be exempt from capital gains tax, should be raised in the UK to at least five years (currently only two, previously ten in 2002). This would help prevent the 'take the money and run' in green tech, which has characterised investments in biotechnology companies, most of which remain 'product-less'. This is a cost saving.
- Short-termism is especially problematic in contexts in which radical technological change is needed and the reason why venture capital and other forms of private equity are not playing a leading role in green technology. Given the lack of private investments, the UK government should step up and increase its 'green' budget. The Green Investment Bank is not enough. This would increase expenditure.

1 From invisible hand to modern myths

The view of the current UK Government regarding its role in stimulating innovation is to create an environment where the private sector can flourish. A growth review by the Department for Business, Innovation and Skills (BIS) and HM Treasury said it is to 'provide the conditions for private sector growth and investment'.[10]

The core of the BIS and Treasury plan outlines the way that government must be limited, reducing red tape and bureaucracy so the private sector can get on with what it does best: investing, innovating, employing:

A new approach to growth requires a new attitude in Government. Government on its own cannot create growth. It is the decisions of business leaders, entrepreneurs and individual workers which build our economy. What the Government can do is provide the conditions for success to promote a new economic dynamism — harnessing our economic strengths, removing the barriers which prevent markets from supporting enterprise, and putting the private sector first when making decisions on tax, regulation and spending.[11]

In a special report on the world economy *The Economist* stated:

A smart innovation agenda, in short, would be quite different from the one that most rich governments seem to favour. It would be more about freeing markets and less about picking winners; more about creating the right conditions for bright ideas to emerge and less about promises like green jobs. But pursuing that kind of policy requires courage and vision — and most of the rich economies are not displaying enough of either.[12]

This view is also espoused by some 'progressive' academics, who argue that the state is limited to:

Creation of the conditions for innovation… accepting that the state will have a vital role in ensuring that market conditions reach the 'just right' balance which will spur innovation and that adequate investment is available for innovators.[13]

This is the view that justifies little more of government than correcting market failures—through investment in basic science, education and infrastructure, for example. This is not a new debate, but it is one that benefits from a greater understanding of the academic literature on the role of innovation in creating economic growth.

More than 250 years ago, when discussing his notion of the 'Invisible Hand' Adam Smith argued that capitalist markets left on their own would self-regulate, with the state's role being limited to that of creating basic infrastructure (schools, hospitals, motorways) and making sure that private property, and other institutions such as 'trust', were nurtured and protected.[14] His background in politics and philosophy meant that his writings were much more profound than the simple libertarian economics position for which he is usually acknowledged, but there is no escaping that he believed that the magic of capitalism consisted in the ability of the market to organise production and distribution without coercion by the state. Karl Polanyi, the acclaimed sociologist of capitalism, has instead shown how the notion of the market as self-regulating is a myth from the historical beginning of markets: 'The road to the free market was opened and kept open by an enormous increase in continuous, centrally organized and controlled interventionism.'[15] In this view, it was the state which imposed the emergence of the market.

John Maynard Keynes believed that capitalist markets, regardless of their origin, need constant regulation because of the inherent instability of capitalism where private business investment (one of the four categories of spending in GDP) is extremely volatile. The reason it is so volatile is that far from being a simple function of interest rates or taxes,[16] it is subject to 'animal spirits'—the gut instinct of investors about future growth prospects in an economy or specific sector.[17] In his view this uncertainty creates constant periods of underinvestment, or overinvestment, causing severe economic fluctuations due to the multiplier effect (whereby an increase or fall in spending is propagated throughout the economy by subsequent rounds of the fall or increase). Unless regulated by increased government spending, falls in spending can lead to the emergence of depressions, a fact of life before Keynes' ideas found their way into post-Second World War economic policies.

More recently, Hyman Minsky focused on the *financial* fragility of capitalism, the way that financial markets cause periodic crises to occur due to cycles of expansion, exaggerated expectations and credit formation, followed by retraction, causing bubbles to burst and asset prices to collapse. He too believed that the state had a crucial role in preventing this vicious cycle from happening, and for growth to follow a more stable path.[18]

Keynes and Minsky focused on the need for the state to intervene in order to bring stability and prevent crises, certainly a pressing issue in today's circumstances. The pamphlet focuses on the role of the state in allowing private and public organisations to interact in such a way that new knowledge is produced and diffused throughout the economy to allow structural change and growth. But to understand the dynamics of such investments it is fundamental first to better understand different perspectives on the theory of economic growth, and the role of technology and innovation in this process.

Where does growth come from?

While growth and the wealth of nations has been the lead concern of economists since Adam Smith, in the 1950s it was shown by Moses Abramovitz and Robert Solow that conventional measures of capital and labour inputs could not account for 90 per cent of economic growth in an advanced industrialised country such as the United States.[19]

It was assumed that the unexplained residual must reflect productivity growth, rather than the quantity of factors of production. And still today there is immense debate among economists over which factors are most important in producing growth. This debate is reflected in politics where different views about growth are espoused with great vehemence, often ignorant of the underlying theoretical assumptions and origins, so well put by Keynes:

The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influence, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back. I am sure that the power of vested interests is vastly exaggerated compared with the gradual encroachment of ideas.[20]

For years, economists have tried to model growth. Neoclassical economics developed its first growth model in the work of Harrod and Domar, but it was Robert Solow who won the Nobel Prize for his growth 'theory'. In the Solow growth model, growth is modelled through a production function where output (Y) is a function of the quantity of physical capital (K) and human labour (L), ceteris paribus—other things remaining equal. What other things? Technological change.

$$Y = F(K, L)$$

Changes in these two inputs cause changes along the function whereas upward or downward shifts in the function would be caused by technological change. When Solow discovered that 90 per cent of variation in output was not explained by capital and labour, he called the residual 'technical change'.[21]

What perhaps should have happened at this point is that if the underlying model is found to be so deficient that it cannot explain 90 per cent of the dependent variable that it is meant to explain, a new model should have been developed. This was indeed what many, such as Joan Robinson, had been arguing for decades, highly critical of the production function framework.[22] Instead technical change was added in. Solow's theory became known as 'exogenous growth theory' because the variable for technology was inserted exogenously, as a time trend A (t) (similar to population growth):

$$Y = A(t)\,F(K, L)$$

As economists became more and more aware of the crucial role that technology plays in economic growth, it became necessary to think more seriously about how to include technology in growth models. This gave rise to 'endogenous' or 'new growth' theory, which modelled technology as the endogenous outcome of an R&D investment function, and as investment in human capital formation.[23] Rather than assuming constant or diminishing marginal returns as in the Solow model (every extra unit of capital employed earned a smaller return), the addition of human capital and technology introduced *increasing returns to scale,* the engine of growth. Increasing returns, which arise from different types of dynamic behaviour like learning by doing, can help explain why certain firms or countries persistently outperform others—there is no 'catch-up' effect.

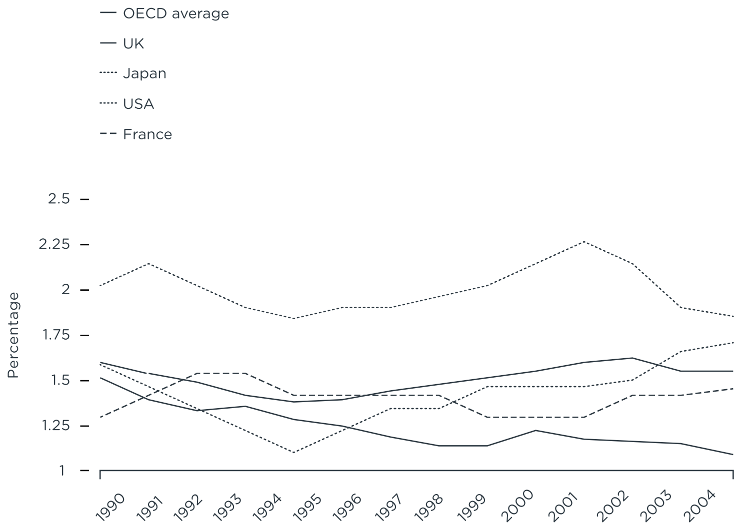
Although new growth theory provided a rational argument for government investment it did not lead to it explicitly. This is because in this framework it was ideas that were endogenous not the institutional framework required to transform ideas into products. Nevertheless, the increasing emphasis on the relationship between technical change and growth indirectly led government policies to focus on the importance of investments in technology and human capital to foster growth, leading to *innovation-led growth* policies in the knowledge economy, a term used to denote the greater importance in the competition process of investing in knowledge creation.[24] Studies that showed a direct relationship between the market value of firms and their innovation performance measured by R&D spending and patents supported these policies.[25]

At the same time, there was an emerging field called Evolutionary Economics. In their ground-breaking *An Evolutionary Theory of Economic Change,* Nelson and Winter argued that in fact the production function framework (exogenous or endogenous) was the wrong one to use to understand technological change. It argued for an 'evolutionary theory' of production (and economic change), which delved inside the 'black box' of the production function to understand how innovation takes place and its effect on growth.[26] In this approach, there is no 'representative agent' but rather a constant process of differentiation among firms, based on their different abilities to innovate because of different internal routines and competencies. Competition in this perspective is about the co-evolution of those processes that create constant differences between firms and the processes of competitive selection that winnow in on those differences, allowing only some firms to survive and grow. In this context, since innovation is firm-specific, and highly uncertain, the types of policies that emerge for supporting innovation are different from those that emerge from a theoretical apparatus that assumes away the heterogeneity and uncertainty, as will be discussed in chapter 3, when we consider national systems of innovation.

R&D targets

The fact that economics was putting so much emphasis on innovation in the growth process caused policy makers, since the 1980s, to begin paying much more attention to variables like research and development (R&D) and patents, as a predicator of innovation and therefore of economic growth.[27] For example, the European Union's Lisbon Agenda (2000) and its current Europe 2020 strategy[28] set a target for 3 per cent of the EU's GDP to be invested in R&D, along with policies that try to encourage the flow of knowledge between universities and business, the creation of credit and venture capital for SMEs, and other factors identified as important for innovation-led growth.[29] UK policy has also put a lot of emphasis on R&D,[30] but as can be seen in figure 1, from 1990 to 2003 the UK ranked below average compared with other major European competitors in its business R&D (BERD) spending.

Figure 1 **Business R&D (BERD) as a percentage of GDP**



Source: OECD Main Science and Technology Indicators 2005[31]

This is not necessarily a problem as the sectors that the UK specialises in—financial services, construction and creative industries (such as music)—are not sectors in which innovation occurs necessarily through R&D.[32] There are many industries, especially in the service sector, that do no R&D. Yet these industries often employ large numbers of knowledge workers to generate, absorb and analyse information. If, all other things equal, these industries represented a smaller proportion of GDP, it would be easier for an economy to reach the 3 per cent target. But would the performance of the economy be superior as a result? It depends on how these industries contribute to the economy. Are these 'low-tech' industries providing important services that enhance the value-creating capabilities of other industries or the welfare of households as consumers? Or are they, as is often the case in financial services, focused on extracting value form the economy, even if that process undermines the conditions for innovation in other industries?[33]

One of the problems that such simple targets encounter is that they divert attention from the vast differences in R&D spending across industries and even across firms within an industry. They can also mask significant differences in the complementary levels of R&D investments by governments and businesses that are required to generate superior economic performance. An even greater problem with R&D-based innovation policies is the lack of understanding of the complementary assets that must be in place to allow technological innovations to reach the market, eg infrastructure or capabilities around marketing.

Myth-busting 1: R&D is not enough

The literature on the economics of innovation, from different camps, has often assumed a direct causal link between R&D and innovation, and between innovation and economic growth. Yet, surprisingly, there are very few studies which prove that innovation carried out by large or small firms actually increases their growth performance — the macro models on innovation and growth do not seem to have strong empirical 'micro foundations'.[34] Some company level studies have found a positive impact of innovation on growth35 while others no significant impact.[36] And some studies have found even a negative impact of R&D on growth, which is not surprising: if the firms in the sample don't have the complementary characteristics needed, R&D becomes only a cost.[37]

It is thus fundamental to identify the company specific conditions that must be present to allow spending on innovation to affect growth. These conditions will no doubt differ between sectors. Demirel and Mazzucato, for example, find that in the pharmaceutical industry, only those firms that patent five years in a row (the 'persistent' patenters) and which engage in alliances achieve any growth from their R&D spending.[38] Innovation policies in this sector must thus target not only R&D but also attributes of firms. Coad and Rao found that only the fastest growing firms reap benefits from their R&D spending (the top 6 per cent identified in Nesta's report 'The vital 6 per cent').[39] And Mazzucato and Parris find that this result, of the importance of high growth firms, only holds in specific periods of the industry life-cycle when competition is particularly fierce.[40]

Myth-busting 2: Small is not necessarily beautiful

This finding that the impact of innovation on growth is indeed different for different types of firms has important implications for the commonly held assumption that 'small firms' matter (for growth, for innovation), and hence for the many different policies that target SMEs. The hype around small firms arises mainly from the confusion between size and growth. The most robust evidence is not on the role of small firms in the economy but the role of *young* high growth firms. Nesta, for example, claims that the most important firms for UK growth have been the small number of fast growing businesses that between 2002 and 2008 generated the highest amount of employment growth in the UK.[41] And while many high growth firms are small, many small firms are not high growth. The bursts of fast growth that promote innovation and create employment are often staged by firms that have existed for several years and grown incrementally until they reach a take-off stage. This is a major problem since so many government policies aim to target tax breaks and benefits to SMEs, with the aim of making the economy more innovative and productive.

Although there is much talk about small firms creating jobs,[42] this is just a myth because while by definition small firms will cause jobs to increase, in fact many small firms also destroy a large number of jobs when they go out of business. Haltiwanger, Jarmin and Miranda find that there is indeed no systematic relationship between firm size and growth.[43] Most of the effect is from age: young firms (and business start-ups) contribute substantially to both gross and net job creation.

Productivity should be the focus, and small firms are indeed often less productive than large firms. Recent evidence has suggested that some economies that have favoured small firms, such as India, have in fact been punished. Hsieh and Klenow, for example, suggest that 40–60 per cent of the total factor productivity (TFP) difference between India and the USA is due to misallocation of output to too many small and low productivity SMEs in India.[44] As most small start-up firms fail, or are incapable of growing beyond the sole owner-operator, targeting assistance to them through grants, soft loans or tax breaks will necessarily involve a high degree of waste.

Bloom and Van Reenan argue that small firms are less productive than large ones because they are less well managed, and subject to provincial family favouritism.[45] Furthermore, small firms have lower average wages, fewer skilled workers, less training, fewer fringe benefits and are more likely to go bankrupt. They argue that the UK has many family firms and a poor record of management in comparison with other countries such as the USA and Germany.[46] Among other reasons, this is related to the fact that the tax system is distorted to give inheritance tax breaks to family firms.

Some have interpreted the result that it is high growth rather than size that matters to mean that the best that governments can do is to provide the conditions for growth innovation. Bloom and Van Reenan argue that instead of having tax breaks and benefits target SMEs, the best way to support small firms is to 'ensure a level playing field by removing entry barriers to firms of all sizes, reducing barriers to growth, enforcing competition policy and strongly resisting the lobbying efforts of larger firms and their agents'.[47] But as we will see in chapters 3 and 5, often the most innovative firms are precisely those that have benefitted the most from direct public investments of different types, making the case much more complex.

Myth-busting 3: Venture capital is not so risk-loving

If the role of small firms and R&D is overstated by policy makers, a similar hype exists in relation to the potential for venture capital to create growth, particularly in knowledge-based sectors where capital intensity and technological complexity are high.

Venture capital is a type of private equity capital focused on early-stage, high-potential, growth companies. The funding tends to come either as seed funding or as later growth funding where the objective is to earn a high return after the IPO of the company or sale. Venture capital fills a void of funding for new firms, which often have trouble gaining credit from traditional financial institutions such as banks and thus often have to rely on other sorts of funding such as 'business angels' (including family and friends), venture capital and private equity. Such alternative funding is most important for new knowledge-based firms trying to enter existing sectors or new firms trying to form a new sector.

Risk capital is so scarce in the seed stage because there is a much higher degree of risk in this early phase, when the technological and demand conditions are completely uncertain. The falling risk in the different phases falls dramatically with the seed financing occurring when there is the most uncertainty about the potential of the new idea (table 1).

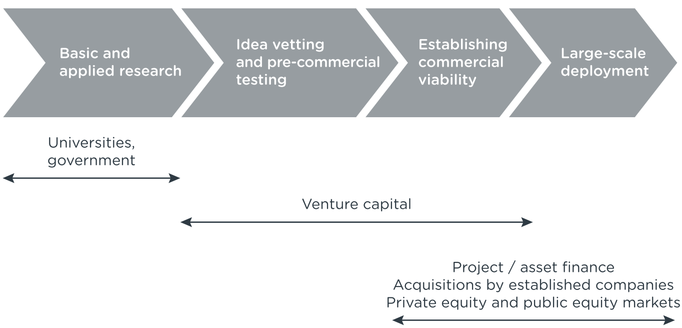
Table 1 **Risk of loss for different stages at which investments are made (%)**

Point at which investment made	Risk of loss
Seed stage	66.2%
Start-up stage	53.0%
Second stage	33.7%
Third stage	20.1%
Bridge or pre-public stage	20.9%

Source: Pierrakis [48]

Figure 2 shows the usual place that it is assumed that venture capital will enter the stage of the invention-innovation process. In reality the real picture is much more non-linear and full of feedback loops. And many firms die during the transition between a new scientific or engineering discovery and its successful commercial transformation and application. Thus the third phase shown in figure 2 of commercial viability is often referred to as the valley of death.

Figure 2 **Stages of venture capital investment**



Source: Ghosh and Nanda [49]

Figure 2 does not illustrate how time after time it has been public rather than privately funded venture capital that has taken the most risks. In the USA, government programmes such as the Small Business Innovation Research (SBIR) programme and the Advanced Technology Program (ATP) in the US Dept of Commerce have provided 20–25 per cent of total funding for early stage technology firms. Thus government has played a leading role not only in the early stage research illustrated in figure 2, but also in the commercial viability stage. Auerswald and Branscomb claim that government funding for early stage technology firms is equal to the total investments of 'business angels' and about two to eight times the amount invested by private venture capital.[50]

Venture capital funds tend to be concentrated in areas of high potential growth, low technological complexity and low capital investment since the latter raises the cost significantly. Since there are so many failures in the high risk area, venture capital funds tend to have a portfolio of different investments with only the tails earning high returns — a very skewed distribution.

Although most venture capital funds are usually structured to have a life of ten years, because of the management fees and the bonuses earned for high returns, venture capital funds tend to prefer to exit much earlier than ten years, in order to establish a track record and raise a follow-on fund. This creates a situation whereby venture capital funds therefore have a bias towards investing in projects where the commercial viability is established within a three to five year period.[51] Although this is sometimes possible (eg Google) it is often not. And surely, in the case of an emerging sector like biotech or green tech today, where the underlying knowledge base is still in its early exploratory phase, such a short term bias is damaging to the scientific exploration process, which requires longer time horizons and more willingness to risk failure.

The role of US venture capital that worked was to provide not only committed finance, but also managerial expertise and ensure the building of a viable organisation.[52]

The problem has been not only the lack of venture capital investment in the most needed early seed stage, but also its objectives in the process. This has been strongly evidenced in the biotech industry where an increasing number of researchers have criticised the model of venture capital in science, indicating that significant investor speculation has a detrimental effect on the underlying innovation.[53] The fact that so many venture-capital-backed biotech companies end up producing nothing, yet make millions for the venture capital firms that sell them on the public market, is highly problematic for the role of venture capital in the development of science and its effect on the growth process. The increased presence of patenting and venture capital is not the right one for allowing risky and long term innovations to come about. Pisano in fact claimed that the stock market was never designed to deal with the governance challenges of R&D entities.[54] Mirowski describes the venture-capital–biotech model as:

commercialized scientific research in the absence of any product lines, heavily dependent upon early-stage venture capital and a later IPO launch, deriving from or displacing academic research, with mergers and acquisitions as the most common terminal state, pitched to facilitate the outsourcing of R&D from large corporations bent upon shedding their previous in-house capacity.[55]

The problem with the model has been that the 'progressive commercialisation of science' seems to be unproductive, with few products, and damage to long-run scientific discoveries and findings over time.

Myth-busting 4: A patent doesn't necessarily mean progress

A similar misunderstanding exists in relation to the role of patents in innovation and economic growth. For example, when policy makers look at the number of patents in the pharmaceutical industry, they presume it is one of the most innovative private sectors in the world. This rise in patents does not however reflect a rise in innovation, but a change in patent laws and a rise in the strategic reasons why patents are being used. This has caused their importance to be greatly hyped up — mythologised.

The exponential rise in patents, and the increasing lack of relationship this rise has had with actual 'innovation' (eg new products and processes), has occurred for various reasons. First, the types of inventions that can be patented has widened to include publicly funded research, upstream research tools (rather than only final products and processes) and even 'discoveries' (rather than only inventions) of existing matter such as genes. The 1980 Bayh-Dole Act, which allowed publicly funded research to be patented rather than remain in the public domain, encouraged the emergence of the biotechnology industry as most of the new biotech companies were new spin-offs from university labs with heavy state funding. Furthermore, the fact that venture capital often uses patents to signal which companies to invest in means that patents have increased in their strategic value to companies that need to attract financing. All these factors have caused the number of patents to rise, with most of them being of little worth (eg very few citations received from other patents) and without resulting in a high number of innovations, eg new drugs in pharma (figure 5). Thus directing too much attention to patents, rather than to specific types of patents, such as those that have high citations, risks wasting much money (as argued below for the patent box case).

Researchers have argued that many of the recent trends in patents, such as the increase in upstream patents (eg patenting of 'research tools'), has caused the rate of innovation to fall rather than increase as it blocks the ability of science to move forwards in an open exploratory way.[56] The effect has been especially deleterious to the ability of scientists in the developing world to repeat experiments carried out in the developed world, before undertaking their own developments on those experiments, thus hurting their ability to 'catch up'.[57]

Notwithstanding the fact that most patents are of little value, and the controversial role that patents play in innovation dynamics, the UK Government insists that patents have a strong link to ongoing high-tech R&D and must thus be incentivised in order for the UK to have innovation-led growth. Thus in October 2010 Osborne announced a patent box policy, due to begin in 2013, which would reduce the rate of corporation tax on the income derived from patents (to 10 per cent). This of course fits with the current government's belief that investment and innovation can be easily nudged via taxes.

The Institute for Fiscal Studies (IFS) has argued against this policy, claiming that the only effect it will have is to reduce government tax revenue (by a large amount) without affecting innovation. It is argued that R&D tax credits are enough to address the market failure issue around R&D, and that the patent box policy is instead poorly targeted at research, as the policy targets the income that results from patented technology, not the research itself (a similar claim we make around R&D tax credits when they are not subject to control). A recent report by the IFS claims:

Once a patent is in place, a firm has a monopoly on the use of those ideas, and so can capture all of the returns and therefore faces the correct incentives to maximise the related income stream. In addition, to the extent that a Patent Box reduces the tax rate for activity that would have occurred in the absence of government intervention, the policy includes a large deadweight cost.[58]

Furthermore, the authors claim that the patent box policy will also add complexity to the tax system and require expensive policing to ensure that income and costs are being appropriately assigned to patents. They claim that the great uncertainty and time lags behind creating patentable technologies will counteract the incentives, and since international collaborations are increasingly common, there is no guarantee that the extra research that is incentivised will be conducted in the UK.[59]

This chapter shows that many of the assumptions that underlie growth policy should not necessarily be taken for granted. Over the last decade or so, policy makers searching for proxies for economic growth have alighted on things they can measure such as R&D spend, patents, venture capital activity, and the number of small firms that are assumed to be important for growth. We have attempted to demystify these assumptions and now turn to the largest myth of all: the limited role for government in producing entrepreneurship, innovation and growth.

2 Beyond market failures

In response to the 2007/08 financial crisis, fiscal consolidation is occurring in national economies across the globe. These 'cuts' have two core stated objectives.

The first objective, most commonly heard in the media, is to reduce the fiscal deficit. This is seen as a danger to the economy, putting at risk the reputation of national bonds, giving rise to increases in interest rates, which then set off a downward spiral of falling investment, employment and consumption. It is also seen as unfair to future generations, which will be forced to pay high rates of interest for the irresponsibility of the current generation.

The second objective is about making the economy more competitive, entrepreneurial and innovative. The idea is that while government spending may be needed to provide basic infrastructure (schools, hospitals, roads) and — for Keynesians — to stabilise GDP, by cutting back on public sector spending the private sector can 'step in' and allow the economy to take off. This is not just because government spending supposedly 'crowds out' the savings that can fund private sector spending (a concept with little foundation when an economy is growing),[60] but also because private sector investment is assumed to lead to a more efficient, dynamic and innovative economy. The assumption is that private companies are inherently more productive than state-run initiatives. So expanding the former and downsizing the latter will make the economy more productive and competitive. The fiscal deficit will fall as a result of the smaller size of the state, but also because of the higher tax receipts that follow from the ensuing growth, even where rates of tax are lowered to promote competitiveness.

In this respect the Big Society programme of the UK's Coalition Government is based on the idea that the state should be made smaller not only to reduce the deficit but because its presence in the economy impedes innovation and dynamism. By allowing local communities to have more control of their resources and decisions, free from the heavy hand of big government, initiatives under the Big Society programme, for example free schools, which are run by local parents and self-help groups, will lead to higher quality, more dynamism and more choice. Schools will become more 'innovative'. Without this assumption, the Big Society is only about cuts, something the government has insisted it is not.

The rhetorical assumption behind all of this is that the role of the state is negative rather than positive. It depicts the state as less productive (by definition) than the private—or voluntary—sector. This pamphlet shows that there is an alternative interpretation of the role of the state, at least in innovation policy, that hotly contests such a view. In this section we explore the role of the state to push forward the boundaries of technological advance through investment in basic science. Although less contested—the Coalition Government's 2010 spending review protected the £4.6 billion science budget at least in cash terms—it shows that many of the innovations that we presume to be a tribute to the dynamism of the market are actually the product of public sector choices.

The debate about what type of research is best conducted by the public or private sector tends to come down to a discussion of the long time horizons necessary (eg for 'basic' research) and the public good nature of the investment in question (making it difficult for businesses to appropriate returns), providing the rationale for public sector funding.[61] This is the classic market failure argument. What is less understood is the fact that often public sector funding ends up doing much more than fixing market failures. By being more willing to engage in the world of Knightian uncertainty, investing in early stage developments, for example dreaming up the possibility of the internet or nanotech when the terms did not even exist, it in fact creates new products and related markets. It leads the growth process rather than just incentivising or stabilising it.

What type of risk?

Entrepreneurship, like growth, is one of the least understood topics in economics. What is it? According to the Austrian economist Joseph Schumpeter, an entrepreneur is a person, or group of people, who is willing and able to convert a new idea or invention into a successful innovation. It is not just about setting up a new business (the more common definition), but doing so in a way that produces a new product, or a new process, or a new market for an existing product or process. Entrepreneurship, he wrote, employs 'the gale of creative destruction' to replace in whole or in part inferior innovations across markets and industries, simultaneously creating new products including new business models, and in so doing destroying the lead of the incumbents.[62] In this way, creative destruction is largely responsible for the dynamism of industries and long-run economic growth. Each major new technology leads to creative destruction: the steam engine, the railway, electricity, electronics, the car, the computer, the internet have all destroyed as much as they have created but led to increased wealth overall.

For Frank H Knight and Peter Drucker entrepreneurship is about taking risk.[63] The behaviour of the entrepreneur is that of a person willing to put his or her career and financial security on the line and take risks in the name of an idea, spending much time as well as capital on an uncertain venture.

In fact, entrepreneurial risk-taking, like technological change, is not just risky, it is highly 'uncertain'. Knight distinguished risk from uncertainty in the following way:

The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome *in a group of instances is known… While in the case of uncertainty that is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique.*[64]

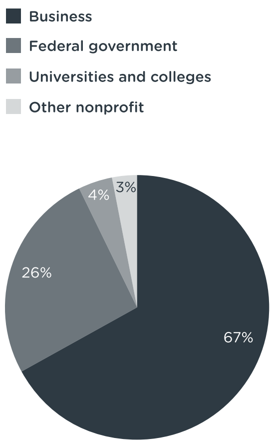
John Maynard Keynes also emphasised these differences:

By 'uncertain' knowledge, let me explain, I do not mean merely to distinguish what is known for certain from what is only probable. The game of roulette is not subject, in this sense, to uncertainty…The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence, or the obsolescence of a new invention… About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know! [65]

Technological change is a good example of the truly unique situation since R&D investments not only take years to materialise into new products, but most lead to failure. In the pharmaceutical sector, for example, innovation takes up to 17 years from the beginning of an R&D project to the end; it costs about $403 million per drug; and the failure rate is extremely high: only 1 in 10,000 compounds reach market approval phase, a success rate of 0.01 per cent. When successful, often the search for one product leads to the discovery of a completely different one. The process is characterised by serendipity.[66] This of course does not mean that innovation is based on luck. Far from it, it is based on long-term strategies and targeted investments. But the returns from those investments are highly uncertain and thus cannot be understood through rational economic theory (as will be seen below, this is one of the critiques that modern day Schumpeterians make of endogenous growth theory, which models R&D as a game-theoretic choice). Furthermore, the ability of companies to engage in innovation differs greatly and is one of the main reasons that firms are so different from each other, and why it is nearly impossible to find firms distributed 'normally' around an 'optimal size firm' (the 'representative' agent), a concept so dear to neoclassical microeconomic theory.

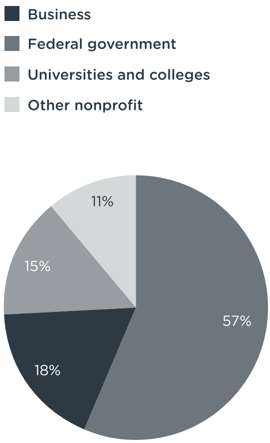
The high risk and serendipitous characteristic of the innovation process is one of the main reasons why profit-maximising companies will invest less in basic research and more in applied research, because of the greater and more immediate returns from the latter. Investment in basic research is a typical example of a 'market failure' where the market alone would not produce enough basic research so the government must step in. This is why there are few people, on all sides of the political spectrum, who would not agree that it should be (and is) the state that tends to fund most basic research. For the US economy, for example, figures 3 and 4 show that while government spending on R&D makes up only 26 per cent of total R&D, with the private sector making up 67 per cent, the proportion is much higher when basic research is considered in isolation. Indeed public spending accounts for 57 per cent of basic research in the USA, with the private sector taking on only 18 per cent.

Figure 3 **Sources of funding for US R&D in 2008**



Source: National Science Foundation [67]

Figure 4 **Sources of funding for basic research R&D in 2008**



Source: National Science Foundation [68]

A core difference between the USA and Europe is the degree to which public R&D spending is for 'general advancement' rather than mission-oriented. Market failure theories of R&D are more useful to understand general 'advancement of knowledge' type R&D than that which is more 'mission-oriented' — R&D investment which is targeted to support a government agency programme, for example in defence, space, agriculture, health, energy or industrial technology. And while public R&D spent on general advancement usually makes up less than 50 per cent of total R&D, in 2003/04 mission-oriented R&D made up more than 60 per cent of public R&D spending in South Korea, the USA, the UK, France, Canada, Japan and Germany.[69]

Mowery argues that trying to cut and paste lessons learned from one mission-oriented programme to another is dangerous as each one has its own specificities (eg defence vs health). And for understanding these differences, he argues the innovation systems approach (reviewed below) is much more useful than the market failure approach, because it is able to take into consideration how each sector and nation has its own dynamics, and how each mission is defined by specific structures, institutions and incentives.

Another important issue in the comparison between European Union (EU) countries and the USA is the so called European Paradox — the conjecture that EU countries play a leading global role in top-level scientific output, but lag behind in the ability to convert this strength into wealth-generating innovations. Dosi, Llerena and Labini provide evidence that the reason for European weaknesses is not the lack of science parks and interaction between education and industry, as is commonly claimed, but a weaker system of scientific research and weaker and less innovative companies.[70] Policy implications include less emphasis on 'networking' and more on policy measures aimed to strengthen 'frontier' research or, put another way, a better division of labour between universities and companies, where universities should focus on high level research and firms on technology development.

State leading in radical innovation

A key reason why the concept of market failure is problematic in understanding the role of government in the innovation process is that it ignores a fundamental fact about the history of innovation. Not only has government funded the riskiest research, whether applied or basic, but it has indeed often been the source of the most radical, path-breaking types of innovation. To this extent it has actively created markets not just fixed them. We will examine this more in depth below in chapter 4 with examples of the leading role that the state played from the development of internet technology to nanotechnology, but here we will consider what it means for our understanding of the link between R&D and growth, and the public–private divide.

Not all innovations lead to economy-wide growth. This is only true for new products or processes that have an impact on a wide variety of sectors in the economy, as was the case with the rise with electricity and computers. These are what economists call general purpose technologies (GPTs) characterised by three core qualities, pervasive, improvement and innovation spawning:

- They are pervasive in that they spread to many sectors.
- They get better over time and, hence, should keep lowering the costs of its users.
- Make it easier to invent and produce new products or processes.

Ruttan argues that large scale and long term government investment has been the engine behind almost every GPT in the last century. He analysed the development of six different technology complexes (the US 'mass production' system, aviation technologies, space technologies, information technology, internet technologies and nuclear power) and concluded that government investments have been important in bringing these new technologies into being, and that nuclear power would, most probably, not have been developed at all in the absence of large government investments in development. In each case it was not just funding innovation, and creating the right conditions for it, but also envisioning the opportunity space, engaging in the most risky and uncertain early research, and overseeing the commercialisation process.[71] In chapter 4 we will show this has also been the case for the recent development of nanotechnology, which many believe is the next GPT.

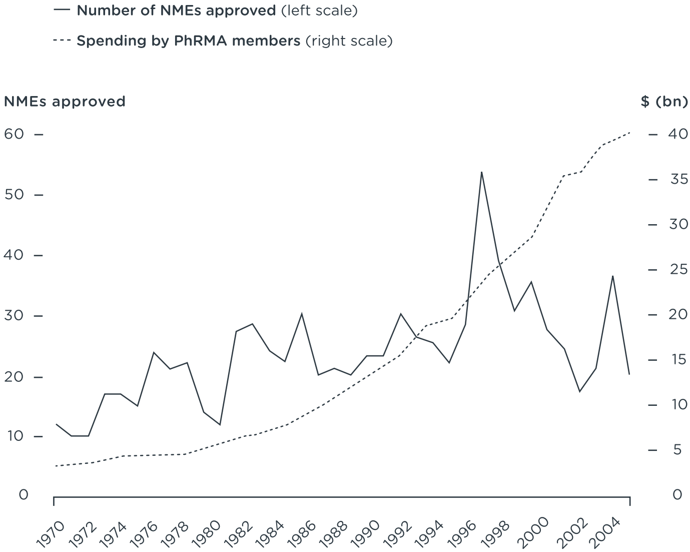
At a more micro level, Block and Keller find that between 1971 and 2006, 77 out of the most important 88 innovations (rated by *R&D Magazine's* annual awards) were found to have been fully dependent on federal support, especially, but not only, in the early phases.[72]

These examples are fundamental for understanding the impact of publicly funded research. It is not just about funding blue sky research but creating visions around new important technologies. To illustrate the general point, we turn now to the specific examples of early-stage government investment into the US pharmaceutical and biotechnology sectors.

The pharmaceutical industry is interesting because of the new division of innovative labour. Large pharma, small biotech, universities and government labs are all parts of the ecology, but it is especially government labs and government backed universities that invest in the research responsible for producing the most radical new drugs—the new molecular entities with priority rating in figure 6. Private pharma has focused more on 'me too' drugs (slight variations of existing ones) and the development (including clinical trials) and marketing side. This is of course highly ironic, given this sector's constant bemoaning of 'stifling' regulations. The ex-editor of the *New England Journal of Medicine,* Marcia Angell, has argued forcefully that while private pharmaceutical companies justify their exorbitantly high prices by saying they are due to their high R&D costs, in fact it has been state funded labs and research that are responsible for two-thirds of the new molecular entities that have been discovered in the last ten years.[73]

Economists measure productivity by comparing the amount of input into production with the amount of output that emerges. In this sense the large pharmaceutical companies have been fairly unproductive over the last few years in the production of innovations. As figure 5 shows there has been an exponential rise in R&D spending by members of the Pharmaceutical Research and Manufacturers of America (PhRMA) with no corresponding increase in the number of new drugs, commonly known as new molecular entities (NMEs). Figure 6 shows that this also holds for patenting: while the number of patents has skyrocketed since the Bayh-Dole Act (1980) allowed publicly funded research to be patented, most of these patents are of little value. When patents are weighted by the amount of citations they receive (the common indicator of 'important' patents), the figure is relatively flat—there are few important patents.

Figure 5 **NMEs approved compared with spending by PhRMA members**



Source: Congressional Budget Office [74]

Between 1993 and 2004, of the 1,072 drugs approved by the FDA, only 357 were NMEs rather than just variations of existing 'me too' drugs. The number of *important* 'priority' new drugs is even more worrying: only 146 of these had priority rating (NME with P rating). In figure 7 we see that only 14 per cent were seen as important new drugs.

Figure 6 **Classifications of new drugs**

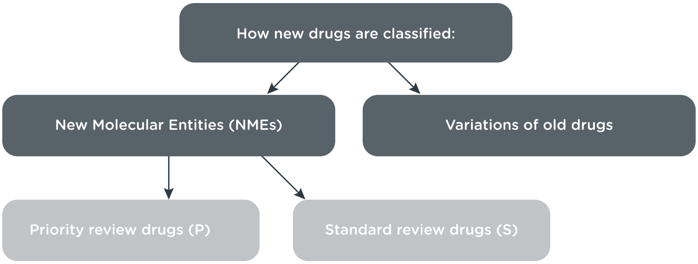
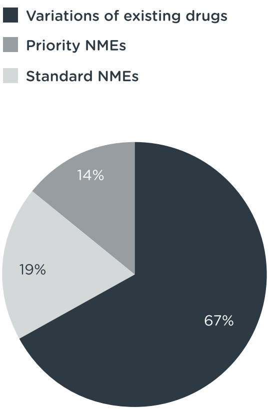


Figure 7 **Percentages of new drugs in the pharmaceutical industry (1993-94)**



Source: Angell [75]

For the sake of the argument being made in this pamphlet, what is important is that 75 per cent of the NMEs trace their research not to private companies but to National Institutes of Health (NIH), publicly funded labs in the USA or other public labs across the globe, such as the MRC in the UK.

So while the state-funded labs have invested in the most risky phase, the big pharmaceutical companies have preferred to invest in the less risky variations of existing drugs (a drug that simply has a different dosage than a previous version of the same drug).

All a far cry, for example, from the recent quote by UK based GlaxoSmithKline[76] CEO Andrew Witty: 'The pharmaceutical industry is hugely innovative… If governments work to support, not stifle, innovation, the industry will deliver the next era of revolutionary medicine.'[77]

Biotechnology: public leader private laggard

In the UK, the MRC receives annual 'grant-in-aid' funding from Parliament through the Department for Business, Innovation and Skills (BIS). It is government funded, though independent in its choice of which research to support. It works closely with the Department of Health and other UK research councils, industry and other stakeholders to identify and respond to the UK's health needs. It was MRC research in the 1970s that led to the development of monoclonal antibodies—which, according to the MRC, make up a third of all new drug treatments for many different major diseases around cancer, arthritis and asthma.

A similar story can be told for the US biopharmaceutical industry. Its growth was not, as is often claimed, rooted in business finance (such as venture capital), but rather emerged and was guided by government investment and spending.[78] In fact, the immense interest of venture capital and big pharmaceutical companies in biotech was paradoxical given the industry's risky and lengthy process of recouping its investment.[79] According to Lazonick and Tulum, the answer to this 'puzzle' is two-fold.[80] First, there has been the availability of an easy exit opportunity for early investors through speculative stock market flotations in which investors are motivated to absorb the initial public offerings (IPOs). Second, there is the significant government support and involvement that has helped this industry to flourish over the last several decades.

In fact, the development of the biotech industry in the USA is a direct product of the key role of the government in leading the development of the knowledge base that has thus provided firm success and the overall growth of the biotech industry. As Vallas, Kleinman and Biscotti eloquently summarise:

The knowledge economy did not spontaneously emerge from the bottom up, but was prompted by a top-down stealth industrial policy; government and industry leaders simultaneously advocated government intervention to foster the development of the biotechnology industry and argued hypocritically that government should 'let the free market work'.[81]

As this quote indicates, not only was this knowledge economy guided by government, but, strikingly, it was done as the leaders of industry were on the one hand privately demanding government intervention to facilitate the industry's development, and on the other hand publicly declaring their support for a free market. It is no wonder given this hypocrisy that so much confusion now exists among policy makers and the general public regarding the development of economic innovation, resulting in the failure to recognise the significance of government involvement. Given the efforts of international policy makers in seeking to advance their own economies and in replicating the successes of the USA, it is imperative now, more than ever, that the 'real' story of this innovation and economic growth and development be told.

Summarising their findings of the strong role of the government in the development of the biotech industry, Vallas, Kleinman and Biscotti emphasise the significance of 'massive shifts in federal R&D that were involved'. They go on to add, 'It is difficult to avoid the conclusion that the knowledge economy was not born but made.' Though pharmaceutical companies spend much on R&D, supplementing these private investments has been completely dependent on a 'ready supply of scientific knowledge that has been either funded or actually produced by federal agencies'.[82]

The National Institutes of Health: creating the wave versus surfing it

State support and involvement in biotech span a wide range of forms, the most significant being that the enormous knowledge base which biopharmaceutical companies are dependent on has developed more from government investment than from business. This knowledge base has been developed from the critical investment the government has given to funding basic science. At the forefront of this lies the National Institutes of Health (NIH) and other government programmes which have invested in many of the key scientific achievements that the industry's success has been built on. Drawing on NIH spending data compiled in Lazonick and Tulum, it is easy to see how crucial this funding was for biotech innovation. From 1978 to 2004, NIH spending on life sciences research totalled $365 billion in 2004. Every year from 1970 to 2009, with the exception of a small decline in 2006, NIH funding increased in nominal terms, in contrast to the widely fluctuating funds from venture capital and stock market investments.[83]

From the NIH's formation in 1938 through 2010, a total $738 billion in 2010 was invested by the US government, and by extension US taxpayers, into the pharmaceutical industry. More striking is that, through 2010, in the 35 years since the founding of Genentech as the first biotech company in 1976, NIH funded $624 billion in 2010 to the biotech industry. As evidenced in this data, Lazonick and Tulum argue that the US government, through the NIH, and by extension via the US taxpayer, 'has long been the nation's (and the world's) most important investor in knowledge creation in the medical fields'.[84] This knowledge base was 'indispensable' and without it, venture capital and public equity funds would not have poured into the industry. They have 'surfed the wave' rather than created it.

Through a system of nearly 50,000 competitive grants, the NIH supports more than 325,000 researchers at over 3,000 universities, medical schools, and other research institutions in every US state and throughout the world.

These grants represent 80 per cent of the agency's budget with another 10 per cent used to directly employ 6,000 individuals in its own laboratories. The agency's 26 research centres in Maryland serve a prominent role in the biotech industry—one that is increasing as more centres and institutes continue to develop within NIH. Beyond these 'knowledge-creating programmes', traces of government support can also be seen in almost every single major biopharmaceutical product in the USA.[85] Although many biotech scholars acknowledge the immense government support in the science base, overall they fail to draw the causal relationship between the successful growth of this industry, its attractiveness and the long lasting government efforts to develop and sustain the substantial knowledge base in this country.

So why does venture capital often get so much credit for creating the biotech revolution? The story of private and public investments in biotech is perfectly described by the following newspaper story:

During a recent visit to the United States, French President Francois Mitterrand stopped to tour California's Silicon Valley, where he hoped to learn more about the ingenuity and entrepreneurial drive that gave birth to so many companies there. Over lunch, Mitterrand listened as Thomas Perkins, a partner in the venture capital fund that started Genentech Inc., extolled the virtues of the risk-taking investors who finance the entrepreneurs. Perkins was cut off by Stanford University Professor Paul Berg, who won a Nobel Prize for work in genetic engineering. He asked, 'Where were you guys in the 50s and 60s when all the funding had to be done in the basic science? Most of the discoveries that have fuelled [the industry] were created back then.' [86]

The point of this chapter is to show that the case for state investment goes beyond blue skies basic research. In fact, it applies to all the different types of 'risky' and uncertain research since the private sector is in many ways less entrepreneurial than the public sector: it shies away from radically new products and processes, leaving the most uncertain investments to be first taken on by the state. So while blue skies research is necessary for innovation to occur, it is far from sufficient, and indeed the role of the state goes far wider. We examine the breadth and depth of state leadership in producing the knowledge economy in chapters 3 and 4.

3 National systems of innovation

In chapter 1 we learned that the relationship between R&D and growth is dependent on firm-specific conditions, with most firms not receiving any growth benefit if those conditions are not in place. One of the most important literatures that have illustrated why 'R&D is not enough' is the work on national systems of innovation. In this view it is not the quantity of R&D that matters but how it is distributed throughout an economy, and often the crucial role of the state in achieving this. This perspective emerges from the 'Schumpeterian' literature on the economics of innovation, which emphasises the Knightian uncertainty that characterises innovation, as discussed in chapter 1.[87]

Schumpetarian economists criticise endogenous growth theory because of its assumption that R&D can be modelled as a lottery where a certain amount of R&D investment will create a certain probability for successful innovation. They argue that in fact innovation is an example of true Knightian uncertainty, not able to be modelled through a normal probability distribution that is implicit in the 'R&D game' literature.[88] By highlighting the strong uncertainty underlying technological innovation, and very strong feedback effects between innovation, growth and market structure, Schumpetarians emphasise the 'systems' component of technological progress and growth.[89] Systems of innovation are defined as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies',[90] or 'the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge… and are either located within or rooted inside the borders of a nation State'.[91]

The emphasis here is not on the stock of R&D but on the circulation of knowledge and its diffusion throughout the economy. Institutional change is not assessed through criteria based on static allocative efficiency but rather on how it promotes technological and structural change. The perspective is neither macro or micro, but more meso, where individual firms are seen as part of a broader network of firms with whom they cooperate and compete. The system of innovation can be inter-firm, regional, national or global. The network is the unit of analysis (not the firm) in the meso perspective. The network consists of customers, subcontractors, infrastructure, suppliers; competencies or functions; and links or relationships. The point is that the competencies for innovation are distributed throughout a network of actors and their links or relationships.[92]

The causation is not 'linear'—from science to large scale R&D to applications and innovations. Rather it is full of feedback loops from market to technology, and from applications to science. In the linear model, the R&D system is seen as the main source of innovation, reinforcing economists' use of R&D stats to understand growth. In this more non-linear view, the roles of education, training, design and quality control are just as important. Furthermore, it is better able to take into account serendipity and uncertainty that characterises the innovation process. It is useful for understanding the rise and fall of different powers in economic history. For example it explains the rise of Germany in the nineteenth century to its technological education and training systems, and the role of the state in fostering these. And it points to the rise of the USA in the twentieth century as related to the rise of mass production and in-house R&D. All of these stories are different in the specifics but share a common seed of having a system of innovation rather than a simple focus on R&D spend in itself.

The general point can be illustrated by contrasting the experience of Japan with that of the then Soviet Union in the 1970s and 1980s. The rise of Japan is explained by the way that new knowledge flowed through a more horizontal structure between ministries of science, academia and company R&D. In the 1970s Japan was spending 2.5 per cent of its GDP on R&D while the Soviet Union was spending more than 4 per cent. Yet Japan eventually grew much faster than the Soviet Union because the R&D was spread across a wider variety of sectors, not just military and space as in the Soviet Union. In Japan, there was a strong integration of R&D, production and import of technology at the enterprise level, whereas in the Soviet Union there was separation. Crucially, the Soviet Union did not have, or permit, business enterprises that could commercialise the knowledge developed by the state. Japan had strong user–producer linkages, which were nonexistent in the Soviet system; and incentives to innovate were encouraged throughout management and the workforce, rather than focused only in the ministries of science. It was the Japanese government's industrial policy that coordinated these attributes guided by the Ministry of International Trade and Industry (MITI). Equally important were the lessons learned by Japanese companies, which sent people abroad to learn about Western technologies. These companies benefitted from the US 'developmental state' and then transferred that knowledge to Japanese companies. Japanese companies were among the first foreign companies to license the transistor from BAT&T (Bell Labs) in the early 1950s. Key connections were made with Western companies such as GE, IBM, HP and Xerox. Particular sectors like electronics were targeted forcefully, and the organisational innovation embodied in the flexible 'just-in-time' production system was applied to a wide variety of sectors.

Table 2 compares the Japanese and Soviet systems of innovation. It is important in this context to highlight that MITI's industrial policy was beyond the 'picking winners' idea that so many opposers today of industrial policy cite. It was about coordinating intra-industrial change, inter-sectoral linkages, inter-company linkages, and the private–public space in a way that allowed growth to occur in a holistic targeted manner. The vertical 'Fordist' model of production in the USA, characterised by rigidity and tense relations between trade unions and management, caused a more rigid flow of knowledge and competencies in the economy, again giving an advantage to the more horizontally structured and flexible Japanese firms.

Table 2 **Contrasting national systems of innovation: Japan and the USSR in the 1970s**

Japan	USSR
High gross domestic expenditure on R&D (GERD)/GNP ratio (2.5%)	Very high GERD/GNP ratio (c 4%)
Very low proportion of military or space R&D (<2% of R&D)	Extremely high proportion of military or space R&D (>70% of R&D)
High proportion of total R&D at enterprise level and company-financed (approx 67%)	Low proportion of total R&D at enterprise level and company-financed (<10%)
Strong integration of R&D, production and import of technology ex enterprise level	Separation of R&D, production and import of technology and weak institutional linkages
Strong user–producer and subcontractor network linkages	Weak or non-existent linkages between marketing, production and procurement
Strong incentives to innovate at enterprise level involving management and workforce	Some incentives to innovate made increasingly strong in 1960s and 1970s but offset by other negative disincentives affecting management and workforce
Intensive experience of competition in international markets	Relatively weak exposure to international competition except in arms race

Source: Freeman, 1995 [93]

Note: Gross domestic expenditures on research and development (GERD) are all monies expended on R&D performed within the country in a given year.

In this context, regional systems of innovation focus on the cultural, geographical and institutional proximity that create and facilitate transactions among socio-economic actors. Studies focusing on innovative milieu such as industrial districts and local systems of innovation have demonstrated that conventions and specific socio-institutional factors in regions affect technological change at a national level. Specific factors might include interactions between local administrations, unions and family owned companies in, for example, the Italian industrial districts.

Government's role in not only creating knowledge (through national labs and universities) but also mobilising resources, and allowing knowledge and innovations to diffuse across sectors and the economy, is key in this view, either through existing networks or by facilitating new ones.

Our view, however, is that having a national system of innovation, rich in horizontal as well as vertical networks, is not sufficient in itself. The state has a further role to play to lead the process of industrial development, developing strategies for technological advance in priority areas.

This has been accepted as consensus in countries that are attempting to catch up with most technologically advanced. There is a whole literature devoted to the role of the so-called 'developmental state', where the state is active not only in Keynesian demand management but also in leading the process of industrialisation. The most typical examples are the East Asian economies, which through planning and active industrial policy were able to 'catch up' technologically and economically with the west.[94] In states that were late to industrialise, the state itself led the industrialisation drive—it took on developmental functions, for example by targeting certain sectors for investment, and putting up barriers to foreign competition until such time as companies in the targeted sectors were ready to export, and then provided assistance to finding new export markets. In Japan, for example, Johnson illustrates how MITI worked to coordinate Japanese firms in new international markets.[95] This occurred through investments in particular technologies (picking winners), with specific business strategies to win in particular markets, domestically and internationally. Furthermore, the Japanese state coordinated finance through the Bank of Japan as well as through the Fiscal Investment Loan Program (funded by the postal savings system).

Chang offers similar illustrations for South Korea and other recently emerged economies.[96] China too has engaged in a very targeted industrialisation strategy, which showed the weaknesses of the Washington consensus on development by only joining the World Trade Organization once its industries were ready to compete, rather than as part of an International Monetary Fund-backed industrialisation strategy, which often denies the state the active role that it played in the development of the industrialised nations (USA, Germany and the UK).

If there is strong evidence that the state can be effective in pursuing targeted catch-up policies by focusing resources on being dominant in certain industrial sectors, why is it not accepted that the state can have a greater role in the development of new technologies and applications beyond simply funding basic science and having an infrastructure to support private sector activity?

The entrepreneurial state

The argument of this pamphlet is that the state can be far more proactive in spurring industrial innovation at the forefront of knowledge than is currently understood by policy makers. Just as developing nations can successfully plan to catch up with Western nations, so any state can spur the development of technological solutions and/or the furtherance of practical knowledge in a given sector simply by catalysing a networked economy to engage in multiple innovations.

Unlike in a developing economy, where the technology is already available elsewhere in the world, an entrepreneurial state does not yet know what the details of the innovation are, but it knows a general area that is ripe for development, or where pushing the boundaries of knowledge are desirable. The state welcomes and engages with Knightian uncertainty for the exploration and production of new products which lead to economic growth.

It has done so not just by funding basic research. More importantly, it has taken the lead by formulating a vision of a new area (for example the internet or the genetic sequence); investing in the earliest-stage research and development which the private sector is unable or unwilling to do (for example when the market prefers to invest in safe 'me too' medicines rather than risky new molecular entities); identifying and supporting multiple new paths and adjusting rules to promote them (for example changes in regulation that allow publicly funded research to be patented); creating and funding networks that bring together business, academia and finance (for example SBIR in the USA); and being constantly ahead of the game in areas that will drive the next decades of growth (for example nanotechnology and green technology today).

It will also, at a time when the economic crisis has given risk and speculation a bad name, distinguish between good speculation and bad speculation. Speculation is needed when the probability of failure is so high.[97] The state has in fact been an important source of Schumpeterian risk and speculation—the bold courage required to delve into the world of uncertainty needed to create new products and processes that can transform long-run economic growth. Thus good risk is the speculation needed for the sake of innovation and structural change rather than speculation for… the sake of speculation—profit on short-term price changes. This 'entrepreneurial' risk-taking role is something that neither the economics of Keynesian stimulus nor the policies behind the Schumpeterian national systems of innovation have elaborated. And this is one of the reasons why the current international debate about post-crisis recovery and growth is often so full of rhetoric about the private–public divide, on both the conservative and progressive sides of the spectrum.

The next chapter argues that despite the perception of the USA as the epitome of private-sector led wealth creation, in reality the state has been engaged on a massive scale in entrepreneurial risk-taking to spur innovation. Four main examples are given: the roles of DARPA, SBIR, the Orphan Drug Act and the National Nanotechnology Initiative in the USA (the EU passed its own Orphan Drug Act in 2001, imitating the US Act passed in 1983). What they share is a proactive approach by the state to shape a market in order to drive innovation. The insight is that as well as being an entrepreneurial society, a place where it is culturally natural to start and grow a business, the USA is also a place where the government itself is entrepreneurial, commissioning high-level innovative private-sector activity in pursuit of public policy goals.

4 The US entrepreneurial state

So far we have established that while the level of technological innovation is integral to the rate of economic growth, there is no linear relationship between R&D spend, size of companies, number of patents and the level of innovation in an economy. What does seem to be clear, however, is that a necessary precursor for innovation to occur is to have a highly networked economy, with continuous feedback loops between different individuals and organisations to enable knowledge to be shared and its boundaries to be pushed back. This is what has been called in the literature a national system of innovation.

This chapter attempts to illustrate that at the frontiers of knowledge, simply having the system of innovation is not enough. Over time, more impressive results can be achieved when the state is a major player operating within this system. This does not necessarily have to take place at a national level (although it can) and should not involve long-term subsidies to certain companies, as gave a bad name to the 'picking winners' experience. Rather the state, through its various agencies and laboratories, can be nimble, using its procurement, commissioning and regulatory functions to shape markets and drive technological advance. In this way it acts as a catalyst for change, the spark that lights the fire, in a networked system that already has the potential to disseminate new ideas rapidly.

The Defense Advanced Research Projects Agency

The history of the USA does not differ from other modern countries in the role that military engagement has had for economic growth and development. But in the USA, the experience of recent decades has been to apply those lessons to far greater application in wider industrial policy. The role of government in the Defense Advanced Research Projects Agency (DARPA) model goes far beyond simply funding basic science. It is about targeting resourcing in specific areas and directions; opening new windows of opportunities; brokering the interactions between public and private agents involved in technological development, including private and public venture capital; and facilitating commercialisation.[98]

In contrast to the emphasis placed on Franklin D Roosevelt's New Deal by market fundamentalists as the critical turning point in US economic history, Block argues that the Second World War served a more significant period for the development of innovation policies in the USA. It was during the period following the Second World War that the Pentagon worked closely with other national security agencies like the Atomic Energy Commission and the National Aeronautics and Space Agency (NASA), which led to the development of technologies such as computers, jet planes, civilian nuclear energy, lasers and biotechnology.[99] The way this was done was 'pioneered' by the Advanced Projects Research Agency (ARPA), an office created by the Pentagon in 1958. This agency, also commonly referred to as the Defense Advanced Research Projects Agency (DARPA) (and consequently the acronym used throughout this pamphlet),[100] engaged in developing critical initiatives across a broad range of technologies. However, it was the support for technological advancement in the computer field that led to the establishment of a new paradigm for technology policy.

DARPA was set up to give the USA technological superiority in different sectors, mainly but not only related to technology, and has always been aggressively mission oriented. It has a budget of more than $3 billion per year, 240 staff, operates flexibly with few overheads, and is connected to but separated from government. It has successfully recruited high quality programme managers who are willing to take risks because of their short term contracts, which last anywhere between four and six years. Its structure is meant to bridge the gap between blue sky academic work, with long time horizons, and the more incremental technological development in the military.

After a Second World War victory that relied heavily on state-sponsored and organised technological developments the federal government was quick to implement the recommendations of Vannevar Bush's 1945 report, which called for ongoing public support for basic as well as applied scientific research.[101] The relationship between government and science was further strengthened by the Manhattan Project (the major scientific effort led by the USA, with the UK and Canada, which led to the atomic bomb in the Second World War), as physicists instructed policy makers on the military implications of new technology. From this point on, it became the government's business to understand which technologies provided possible applications for military purposes as well as commercial use.

According to Block, during this period an increased number of government workers adopted a more direct role in advancing innovation through encouraging researchers to solve specific problems, procuring additional researchers and requiring that those researchers meet specific objectives.[102] The insight that followed was that this was something government could do for economic and civilian purposes, in addition to the traditional military function.

The launching of Sputnik in 1957 by the Soviets led to the eruption of panic among US policy makers, fearful that they were losing the technological battle. The creation of DARPA in 1958 was a direct result. Before the formation of DARPA the military was the sole controller of all military R&D dollars. Through the formation of DARPA a portion of military spending on R&D was now designated to 'blue sky thinking'—ideas that went beyond the horizon in that they may not produce results for ten or 20 years. As a result of this mandate DARPA was free to focus on advancing innovative technological development with novel strategies. This opened numerous windows for scientists and engineers to propose innovative ideas and receive funding and assistance.[103]

Going way beyond simply funding research, DARPA funded the formation of computer science departments, provided start-up firms with early research support, contributed to semiconductor research and support to human computer interface research, and oversaw the early stages of the internet. Many of these critical activities were carried out by its Information Processing Techniques Office, originally established in 1962. Such strategies contributed hugely to the development of the computer industry during the 1960s and 1970s, and as a variety of research reveals, many of the technologies later incorporated in the design of the personal computer were developed by DARPA-funded researchers.

Another key event during this period was the new innovation environment that emerged after a group of scientists and engineers in 1957 broke away from a firm started by William Shockley.[104] This rebellious group of scientists and engineers often referred to as the 'traitorous eight' went on to form a new firm that advanced semiconductor technology and continued 'a process of economic fission that was constantly spinning off new economic challengers'. This spin-off business model became viable and popular for technological advancement following the 1957 revolt. A new paradigm emerged that resulted in innovative ideas moving from labs to the market in far greater quantity.

Before this government officials' leverage in generating rapid technological advancement was limited as large defence firms still wielded tremendous power in deflecting pressure and demands for innovation. The leverage government officials had in advancing innovative breakthroughs was also limited by the small number of firms with such capabilities. Bonded by a shared interest in avoiding the certain risks that accompanied following an uncertain technological path, the firms resisted government pressure for innovation. However, in a new environment with ambitious start-ups the opportunity for generating real competition among firms presented itself more fully.

Programme officers at DARPA recognised the potential this new innovation environment provided and were able to take advantage of it focusing at first on new, smaller firms to whom they could provide much smaller funds than was possible with the larger defence contractors. These firms recognised the need for ambitious innovation as part of their overall future viability. With small, newer firms engaged in real competition and as the spin-off model became more institutionalised, Block notes that large firms also had to get on board with this quest for rapid innovative breakthroughs.[105] By taking advantage of this new environment, the government was able to play a leading role in mobilising innovation among big and small firms, and in university and government laboratories. The dynamic and flexible structure of DARPA in contrast to the more formal and bureaucratic structure of other government programmes allowed it to maximise the increased leverage it now had in generating real competition across the network. Using its funding networks, DARPA increased the flow of knowledge across competing research groups. It facilitated workshops for researchers to gather and share ideas while also learning of the paths identified as 'dead ends' by others. DARPA officers engaged in business and technological brokering—linking university researchers to entrepreneurs interested in starting a new firm; connecting start-up firms with venture capitalists; finding a larger company to commercialise the technology; or assisting in procuring a government contract to support the commercialisation process.

Pursuing this brokering function, DARPA officers not only developed links among those involved in the network system but also engaged in efforts to expand the pool of scientists and engineers working in specific areas. An example of this is the role DARPA played in the 1960s by funding the establishment of new computer science departments at various universities in the USA. By increasing the number of researchers who possessed the necessary and particular expertise, DARPA was able, over an extended period of time, to accelerate technological change in this area. In the area of computer chip fabrication during the 1970s, DARPA assumed the expenses associated with getting a design into a prototype by funding a laboratory affiliated with the University of Southern California. Anyone who possessed a superior design for a new microchip could have the chips fabricated at this laboratory, thus expanding the pool of participants designing faster and better microchips.

The personal computer emerged during this time with Apple introducing the first one in 1976. Following this, the computer industry's boom in Silicon Valley and the key role of DARPA in the massive growth of personal computing received significant attention, but has since been forgotten by those who claim Silicon Valley is an example of 'free market' capitalism.

Also during the 1970s the significant developments taking place in biotechnology illustrated to policy makers that the role of DARPA in the computer industry was not a unique or isolated case of success. The decentralised form of industrial policy that played such a crucial role in setting the context for the dramatic expansion of personal computing was also instrumental in accelerating growth and development in biotechnology.

Block identifies the four key characteristics of the DARPA model:[106]

A series of relatively small offices, often staffed with leading scientists and engineers, are given considerable budget autonomy to support promising ideas. These offices are proactive rather than reactive and work to set an agenda for researchers in the field. The goal is to create a scientific community with a presence in universities, the public sector and corporations that focuses on specific technological challenges that have to be overcome.

Funding is provided to a mix of university-based researchers, start-up firms, established firms and industry consortia. There is no dividing line between 'basic research' and 'applied research', since the two are deeply intertwined. Moreover, the DARPA personnel are encouraged to cut off funding to groups that were not making progress and reallocate resources to other groups that have more promise.

Since the goal is to produce usable technological advances, the agency's mandate extends to helping firms get products to the stage of commercial viability. This can involve the agency in providing firms with assistance that goes well beyond research funding.

Part of the agency's task is to use its oversight role to make constructive linkages of ideas, resources and people across the different research and development sites.

The main focus is to assist firms in developing new product and process innovations. The key here is that the government serves as a leader for firms to imitate, an approach that is much more 'hands on' in that public sector officials are working directly with firms in identifying and pursuing the most promising innovative paths.

The Small Business Innovation Research programme

Contrary to conventional wisdom regarding the domination of free market ideology during the Reagan Administration, the US government in the 1980s, in fact, acted to build on the successes of DARPA's decentralised industrial policy. One of the most significant events during this period was the signing of the Small Business Innovation Development Act by Reagan in 1982, as a consortium between the Small Business Administration and different government agencies like the Department of Defence, Department of Energy and Environmental Protection Agency. The Act was based on a National Science Foundation (NSF) pilot programme initiated during the Carter administration. The Small Business Innovation Research (SBIR) programme required government agencies with large research budgets to designate a fraction (originally 1.25 per cent) of their research funding to support initiatives of small, independent, for-profit firms. The programme has provided support to a significant number of highly innovative start-up firms.[107]

In addition, the network of state and local institutions that worked in partnership with the federal programmes was expanded. An example of this is the development of organisations that were funded by state and local governments to assist entrepreneurs in submitting successful applications to the SBIR programme to secure funds for their projects. The SBIR programme fulfils a unique role in this new innovation system, because it serves as the first place many entrepreneurs involved in technological innovation go for funding. The programme, which provides more than $2 billion per year in direct support to high-tech firms, has fostered development of new enterprises, and has guided the commercialisation of hundreds of new technologies from the laboratory to the market. Given the instrumental role of the SBIR programme and its successes, it is surprising how little attention this programme receives, although the UK has latterly attempted to copy its success, but to little avail so far, as we will see in the next chapter.

Block highlights the lack of visibility of SBIR in an effort to illustrate what he describes as 'a discrepancy between the growing importance of these federal initiatives and the absence of public debate or discussion about them'.[108] As indicated in the introduction of this pamphlet and again in the early stages of this chapter, this discrepancy poses an exceptional challenge to the policy makers and the public who are engaged in economic debates and efforts to address the current economic crises and pave the way for the future of innovation and development in the globalised world.

Orphan drugs

A year after the SBIR programme was established, a further legislative spur to private sector innovation occurred, this time specific to the biotech industry. The 1983 Orphan Drug Act (ODA) made it possible for small, dedicated biotech firms to carve a slither from the drug market. The act includes certain tax incentives, clinical as well as R&D subsidies, fast-track drug approval, along with strong intellectual and marketing rights for products developed for treating rare conditions. A rare disease is defined as any disease that affects less than 200,000 people and given this potentially small market, it was argued that without financial incentives these potential drugs would remain 'orphans'. The impetus behind this legislation was to advance the investment of pharmaceutical companies in developing these drugs.

The protection provided by the act enables small firms to improve their technology platforms and scale up their operations, enabling them to advance to the position of becoming a major player in this industry. In fact, orphan drugs played an important role for the major biopharmaceutical firms such as Genzyme, Biogen, Amgen and Genentech to become what they are today. Since the introduction of this legislation, 2,364 products have been designated as orphan drugs and 370 of these drugs have gained marketing approval.[109]

In addition to the generous tax incentives, subsidies, access to fast-track approval and extensive intellectual and marketing rights for products designated as 'orphan' drugs, Lazonick and Tulum draw attention to the fact that a drug can be designated as 'orphan' for multiple indications.[110] The example of Novartis illustrates this point. In May 2001 the company received marketing approval by the FDA with market exclusivity for its 'chronic myelogenous leukemia' drug Gleevec under the Orphan Drug Act. In 2005 over a span of five months, Novartis applied for and was later granted orphan drug designation for five different indications for this same drug. According to the company's 2010 annual report, Gleevec recorded sales globally in 2010 were $4.3 billion, thus confirming the point raised by Lazonick and Tulum, that even when the market size for a drug is small, the revenues can be considerable.[111]

When it comes to the substantial revenues that are generated from drugs designated as 'orphan' it is not only small firms that appear to be benefiting. Some of the world's largest pharmaceutical firms such as Roche, Johnson & Johnson, GlaxoSmithKline and Pfizer among others have applied for orphan drug designation. The National Organization for Rare Disorders, a non-profit public organisation largely funded by federal government, has been encouraging large pharmaceutical firms to share their redundant proprietary knowledge, through licensing deals, with the smaller biotech firms to develop drugs for orphan indications. Lazonick and Tulum explain the importance of this legislation by calculating the share of orphan drugs within total product revenues for major biopharmaceutical firms.[112] The financial histories of the six leading bio-pharmaceutical (BP) companies reveal a dependence on orphan drugs as a significant portion of the companies' overall product revenues. In fact, 59 per cent of total product revenues and 61 per cent of the product revenues of the six leading dedicated biopharmaceutical firms come from orphan drug sales. When this calculation also includes the later generation derivatives of drugs that have orphan status, the figure (calculated for 2008) goes up to 74 per cent of total revenues and 74 per cent of the product revenues for the six leading biopharmaceutical firms. Comparing the timing and growth of revenues for orphan and non-orphan 'blockbusters', Lazonick and Tulum show that orphan drugs are more numerous, their revenue growth began earlier, and many of them have greater 2007 sales than leading non-orphan drugs.[113]

The central role that orphan drugs have played in leading the development of the biotech industry is undeniable, yet this is just one of many critical moves the US government made in supporting the biotech industry. It is also evident that big pharma plays a significant role in the biopharmaceutical industry, as illustrated in analyses of orphan drugs. The two (big pharma and the biotech industry) are significantly dependent on one another in this area, and the distinction between big pharma and big biopharma has become 'blurred'. However, the role of government for both these areas was crucial to their development and success. Lazonick and Tulum summarised the government's role for both during the 2000s:

The US government still serves as an investor in knowledge creation, subsidizer of drug development, protector of drug markets, and, last but not least… purchaser of the drugs that the biopharmaceutical companies have to sell. The BP industry has become big business because of big government, and… remains highly dependent on big government to sustain its commercial success.[114]

From this brief overview of these three examples — DARPA, SBIR and orphan drugs — a general point can be drawn: the USA has spent the last few decades using active interventionist policies to drive private sector innovation in pursuit of public policy goals. What all three interventions have in common is that they do not tie the shirt-tails of government to any one firm; no accusations of lame-duck industrial policy here. Instead it is a nimble government that rewards innovation and directs resources over a relatively short time horizon to the companies that show promise, through either supply-side (DARPA) or through demand side and start up interventions (SBIR and orphan drugs). Either way, the government has not simply created the 'conditions for innovation', but actively funded the early radical research and created the necessary networks between state agencies and the private sector to allow the commercial development to occur. This is very far from current UK government policy, which assumes that the state can simply nudge the private sector into action.

The National Nanotechnology Initiative

The entrepreneurial role that the state can play in creating strategic decisions in how to foster the development of new technologies, which provide the foundation for decades of economic growth, has most recently been seen in the development of nanotechnology in the USA. The types of investments that the state has made have gone beyond simply creating the right infrastructure, funding basic research and setting rules and regulations.

Nanotechnology is very likely to be the next general purpose technology, having a pervasive effect on many different sectors and being the foundation of economic growth. However, while this is commonly accepted now, in the 1990s it was not. Motoyama, Appelbaum and Parker describe in detail how the US government has in fact been the lead visionary in dreaming the possibility of a nanotech revolution — making the 'against all odds' initial investments, and explicitly forming dynamic networks between different public actors (universities, national labs, government agencies) and when available, the private sector, to kick start a major new revolution, which many believe will be even more important than the computer revolution.[115] It has even been the first to 'define' what nanotechnology is.

It did so through the active development of the National Nanotechnology Initiative (NNI). Motoyama, Appelbaum and Parker describe how it was set up:

The creation and subsequent development of the NNI has been neither a purely bottom-up nor top-down approach: it did not derive from a groundswell of private sector initiative, nor was it the result of strategic decisions by government officials. Rather it resulted from the vision and efforts of a small group of scientists and engineers at the National Science Foundation and the Clinton White House in the late 1990s… It seems clear that Washington selected nanotechnology as the leading front runner, initiated the policy, and invested in its development on a multi-billion dollar scale.[116]

The government's objective was to find the 'next new thing' to replace the internet. After receiving 'blank stares', the key players (civil servants) in Washington convinced the US government to proceed to invest in creating a new research agenda, and to prepare a set of budget options and a clear division of labour between the different agencies. It even had first to define nanotech. They did so by arguing that the private sector could not expect to lead applications of nanotech that were still so far away (10–20 years) from the commercial market:

Industry generally invests only in developing cost-competitive products in the 3 to 5 year time frame. It is difficult for industry management to justify to their shareholders the large investments in long-term, fundamental research needed to make nanotechnology-based products possible. Furthermore, the highly interdisciplinary nature of the needed research is incompatible with many current corporate structures.[117]

This quote is fascinating because of the way it highlights how the private sector is too focused on the short term (mainly but not only as a result of the effect the 1980s shareholder revolution has had on long-term thinking of business) and its rigid structures. Far from being less innovative than the private sector, government has shown itself to be more flexible and dynamic in understanding the connections between different disciplines (physics, chemistry, materials science, biology, medicine, engineering and computer simulation). As Block and Keller discuss, government actions around cutting edge new technologies have often had to remain veiled behind a 'hidden' industrial policy.[118] The public sector activists around nanotechnology had to continuously talk about a 'bottom-up' approach so that it would not seem to be too heavily 'picked' and championed. Though in the end, 'While most of the policy making process involved consultation with academics and corporate experts, it is clear that the principal impetus and direction—from background reports to budget scheme—came from the top.'[119] The approach succeeded in convincing Clinton, and then Bush, that investments in nanotechnology would have the potential to 'spawn the growth of future industrial productivity' and that the 'the country that leads in discovery and implementation of nanotechnology will have great advantage in the economic and military scene for many decades to come'.[120]

In the end, the US government took action. It not only selected nanotechnology as the sector to back most forcefully ('picking it' as a winning sector), but also proceeded to launch the NNI, review rules and regulations concerning nanotech by studying the various risks involved, and become the largest investor, even beyond what it has done for biotech and the life sciences. Although the strongest action was carried out top down by key senior level officers in the NSF and the White House, the actual activity behind nanotech was, as in the case of the internet and computers, heavily decentralised through various state agencies (a total of 13, led by the NSF, but also involving the NIH, the Defense Department and SBIR). Across these different agencies, currently the US government spends approximately $1.8 billion annually on the NNI.

Nanotechnology today does not yet have a major impact because of the lack of commercialisation of new technologies. Motoyama, Appelbaum and Parker claim that this is due to the excessive investments in research, and lack of investments in commercialisation.[121] They call for more active government investment in commercialisation. However, this raises the question, if government has to do the research, fund major infrastructure investments and undertake the commercialisation, what is the role of the private sector?

This chapter has highlighted the important role that government has played in leading innovation and economic growth. Far from stifling innovation and being a weight to the system, it has fostered innovation and dynamism in many industries, with the private sector often taking a back seat. Ironically it has often done so in the USA, which in policy circles is often discussed as following a more 'market' oriented model than Europe. This has not been the case where innovation is concerned. It is to the implications of this experience for UK policies that we now turn.

5 Lessons for the UK

One of the core messages of this pamphlet is that the history of technological change suggests that the key role of government is not about fixing market failures, but rather about actively creating the market for the new technologies by envisioning the opportunity space and allowing the right network of private and public actors to meet in order for radical innovation to occur. The role of government has, in this sense, been more about fixing 'network failures' than about 'market failure'. It has also been about preventing 'opportunity failures'—government's willingness to think big and take risks has created new opportunities and markets, whereas the private sector has shied away because of the long time horizons and the high failure rates.

An article in *The Economist* recently claimed that the 'government has a terrible record at picking winners'.[122] A look at the massive impact that government's targeted large investments in industries such as steel, railways, air travel, silicon microchip manufacturing, automotive manufacturing, computer, biotechnology and the internet, and nanotechnology shows this is just not true. Without the government pursuing a targeted investment strategy, none of these industries would have come into being. And being first matters because of the strong economies of scale.

In this respect, Britain has got its innovation policy all wrong, with negative implications for growth in the long run. Taxpayer support is misdirected and opportunities are being missed. Innovation policy needs to focus on creating the conditions that allow innovation to flourish, but also, and perhaps especially, on directly commissioning and procuring innovative solutions. History tells us that these will not happen without a strong push by the state. Here are some suggestions of improvements that can be made.

Cost neutral opportunity: reform the Small Business Research Initiative programme

The UK Government has recently tried to copy the success of the US Small Business Innovation Research (SBIR) programme by setting up in 2001 a scheme entitled the Small Business Research Initiative (SBRI), which is meant to act as a cross-departmental initiative improving the success of small R&D-based businesses in obtaining contracts from government bodies. With a target rate of 2.5 per cent, the initial objective was to place £50 million of government R&D contracts per annum with SMEs through the SBRI website. However, by 2004, contracts worth only £2 million per year were being advertised and none of the key departments participated.[123] Following pressure, in particular from Cambridge-based innovation policy lobby groups, the SBRI was relaunched through the supply2.gov.uk web portal but a subsequent evaluation by the Richard report showed that two years later the scheme still bears no real resemblance to the US SBIR, mainly because hardly any of the projects actually involve R&D (for example contracts to supply Chinese books to local authority libraries), and many were research councils seeking grant proposals from academic researchers, and for which businesses are ineligible to apply.[124] Furthermore, the maximum size of contracts typically covered by the supply2gov database is £100,000, compared with a typical size of $850,000 under US SBIR. The UK SBRI has suffered from a lack of ministerial attention and the fact that it is at odds with the culture of the procurement offices of national government. The 2011 budget included a welcome commitment to commit £20 million over the next two years to the SBRI, half of which would be earmarked for specific competitions to meet healthcare challenges. However, this is a drop in the ocean and should be dramatically increased within current procurement budgets in line with the US example.

Cost saving: cut blanket support to small firms

In chapter 1 we saw that there is not much of a relationship between being small and having potential to grow. Yes, fast growing firms start out small but plenty of other small firms are not fast growing, nor do they want to be. Many smaller businesses have lower productivity because they are less well managed than larger firms, sometimes because they are more likely to be family-owned and family-run. Rather than giving handouts to small companies in the hope that they will grow it is better to give contracts to young companies that have already demonstrated ambition; it is more effective to commission the technologies that require innovation than hand out subsidies in the hope that innovation will follow. This approach could yield significant taxpayer savings if, for example, direct transfers to firms that are given just because of their size were ended, such as small business rate relief for smaller companies and inheritance tax relief for family firms.[125]

Cost saving: shift from R&D tax credits to commissioning R&D

Similarly, while there is a research component in innovation, there is not a linear relationship between research and development and economic growth. While it is important that the frontiers of science advance, and that economies develop the nodes and networks to enable knowledge to be transferred between different organisations and individuals, it does not follow that it is the best use of taxpayers' money to subsidise the activity of R&D per se within individual firms. Although it is common sense that there is a relationship between a decision to engage in R&D and its cost, qualitative surveys of the effectiveness of the R&D tax credit for both large and small firms provide little evidence that it has positively impacted on the decision to engage in R&D, rather than simply providing a welcome cash transfer to some firms that have already done so.[126] There is also a potential problem under the current R&D tax credit system that it does not hold firms accountable for whether they have conducted new innovation that would not otherwise have taken place, or simply undertaken more routine forms of product development. In time, therefore, as the entrepreneurial state is built, it would be more effective to use some of the expenditure on R&D tax credits to directly commission the technological advance in question.

Cost saving: do not be distracted by low-tax enterprise zones

Related to the specific issue about R&D tax credits is the more general point that investment in innovation is generally not very sensitive to taxes. As Keynes emphasised, business investment (especially innovative investment) is a function of 'animal spirits', the gut instinct of investors about future growth prospects. These are more affected by the strength of a nation's science base, its system of credit creation, and quality of education and hence human capital rather than taxes. Tax cuts in the 1980s did not produce more investment in innovation, only affecting income distribution (increasing inequality). For this same reason, 'enterprise zones' which are focused almost exclusively on benefits related to tax and weakened regulation are not innovation zones. Best to save that money or to invest it in properly run science parks.[127]

Cost saving: do not implement the patent box

As discussed in chapter 2, firms are increasingly producing patents of little value. In this sense, patents are overly emphasised as necessary for innovation to occur. In fact, evidence has suggested that many firms can appropriate their innovations through other measures, and that the increase in patenting has not led to an increase in the rate of innovation.[128] Notwithstanding this evidence, the UK Government claims that patents have a strong link to ongoing high-tech R&D and has thus suggested a patent box — a preferential regime for profits arising from patents — to reward patent holders. This idea has been criticised ferociously by the Institute for

Fiscal Studies as being a waste of money and not encouraging research. The patent box will not stimulate the types of innovation that are needed because it only targets the income earned from patents not the research itself (a similar claim we make above about R&D tax credits, since historically they have been badly controlled so that it is not clear that the money has been spent on research). The patent box and many SBRI programmes direct returns to potentially mediocre and non innovative companies rather than the leaders of innovation. Furthermore, patents are increasingly being applied to upstream areas like research tools, stunting rather than encouraging research (and replication), putting the open science system at risk.[129]

Additional expenditure: massive reform and expansion of technology strategy board

The Government should implement the recommendations the CBI made in 2006 to reform the UK Technology Strategy Board (TSB) along the US DARPA model.[130] With a much expanded budget, the TSB should therefore become more of a dynamic commissioner of innovative solutions at the frontiers of innovation and research. It should welcome (rather than shy away from) the risky territory of blue sky research, facilitating networking between business and academia, and engaging in pre-commercial procurement to a far greater extent.

The UK Government should create a vision whereby the TSB can bring together government departments, research councils, local economic partnerships and other public bodies to address specific challenges, such as those around green technology. If the TSB functioned in this way it would demonstrate that the core innovation problem is not one of 'market failure' but rather one of 'network failure', and show it understands the government's role in creating and leading those networks. As Dosi, Llerena and Labini emphasise, for such a network to function properly, the different agents in the network must be strong not weak.[131] Hence fundamental to this strategy will be a strong science base in UK universities and public laboratories. The fact that UK science is falling behind that of its main competitors is worrying.[132]

An enhanced model for the TSB would be emblematic of a shift of the UK government away from a system where technological challenges are showered with tax incentives, subsidies and pricing debates (the latter in the case of pharmaceuticals) and more to a system where the government commissioned solutions to specific problems and catalysed potential opportunities from the private sector, without necessarily specifying how these should be achieved.

The TSB and other BIS schemes should focus more on those private-public ecologies that will enable radical innovation to emerge. It is especially radical innovation that embodies the type of Knightian uncertainty that private venture capital shies away from, and it is especially in this area that the leading role of the public sector is essential. This involves supporting the full span of activities that were discussed in chapters 3 and 4.

Cost saving: retain proportion of ownership of state-backed intellectual property

Where technological breakthroughs have occurred as a result of targeted state interventions, there is potential for the state, over time, to reap some of the financial rewards, by retaining ownership over a small proportion of the intellectual property created. This is not to say the state should ever have exclusive licence or hold a large enough proportion of the value of an innovation that it deters a wider spread of its application — the role of government is not to run commercial enterprises, but to spark innovation elsewhere. But government should explore whether it is possible to own a slither of the value it has created, which over time could create significant value and then be reinvested into growth-generating investments.

For example, we saw in chapter 1 that three-quarters of the new molecular bio-pharmaceutical entities owe their creation to publicly funded laboratories. Yet in the past ten years, the top ten companies in this industry have made more in profits than the rest of the Fortune 500 companies combined. The industry also enjoys great tax advantages: its R&D costs are deductible, and so are many of its massive marketing expenses, some of which are counted as R&D.[133]

After taking on most of the R&D bill, the state often gives away the outputs at a rock bottom rate. For example, Taxol, the cancer drug discovered by the National Institutes of Health (NIH), is sold by Bristol-Myers Squibb for $20,000 per year's dose, 20 times the manufacturing cost. Yet, the company agreed to pay the NIH only 0.5 per cent in royalties for the drug.

Similarly, where an applied technological breakthrough is directly financed by the government, it should in return be able to extract a small royalty from its application. Again, this should not be sufficient as to prohibit its dissemination throughout the economy, or to disincentivise the innovators from taking the risk in the first place. Instead it makes the policy of spending taxpayers' money to light the innovative spark more sustainable, by enabling part of the financial gains from so doing to be recycled directly back into the programme over time.

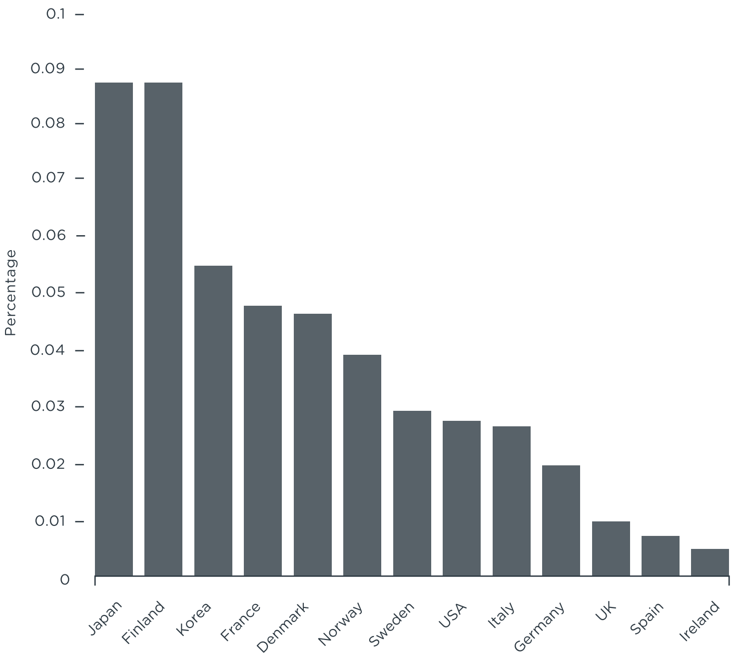
Green technologies

There is currently a global race to be the leader in green technologies. Britain has a potential to do well in this race but is in danger of being left behind. The remainder of this chapter considers the application of what has been learnt so far to spur greater innovations with green technology application.

In the USA the stimulus packages included 11.5 per cent of the budget devoted to green investment, but in the UK the figure is only 6.9 per cent, far lower than China (34.3 per cent), France (21 per cent) or South Korea (80.5 per cent).[134] In fact, in July 2010 the South Korean Government announced that it would double its spending on green research to the equivalent of £1.9 billion by 2013 (almost 2 per cent of its annual GDP), which means that between 2009 and 2013 it will have spent £59 billion on this type of research.

This is not a new problem. Data for 2007 show the UK near the bottom of the league when comparing government investment in energy R&D, spending less than US and Asian competitors and some other European countries (figure 8). The problem is that the private sector is not coming in to fill the gap so, overall, the UK's investment of 12.6 billion in 2009/10[135] is, according to PIRC, 'under 1 per cent of UK Gross Domestic Product; half of what South Korea currently invests in green technologies annually; and less than what the UK presently spend on furniture in a year'.[136]

Figure 8 **Government funded energy R&D as a percentage of GDP (2007)**



Source: Committee on Climate Change, 2010 [137]

Despite the Prime Minister's pledge in 2010 to lead 'the greenest government ever',[138] in reality the spending cuts have caused established programmes in these areas to be scaled back. In 2010/11, £85 million was cut from the Department of Energy and Climate Change budget, including £34 million from the renewable support programmes. Furthermore, 40 per cent cuts have been applied to the 2011 budget of the Carbon Trust and 50 per cent cuts to the Energy Saving Trust:

Combined with a reluctance to guarantee sources of green finance over the long term—including failing to guarantee grants for electric cars beyond one year, and pledging to review the Feed-In Tariff structure in 2012—these moves have not created an optimum environment for green investment.[139]

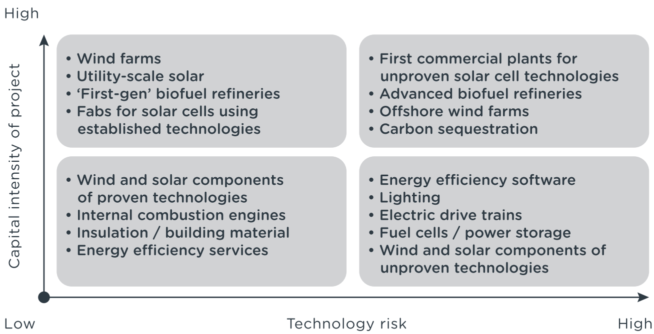
An April 2011 revision has already halved the feed-in tariff for commercial installations above 50kW in order to fund the promised support for small residential installations. Nor has the effect of previous initiatives been proven: the April 2009 budget tried to accelerate emissions reduction in power generation by requiring carbon capture and storage (CCS) to be fitted to all new coal-fired stations (and retrofitted to all existing stations by 2014); yet according to the House of Commons Energy and Climate Change Committee, this could just lead to a renewed expansion of gas-fired generation rather than substantial investment in CCS technology.[140]

This fits a broader picture of how EU countries are responding to current economic circumstances. Ernst and Young report a record global investment (including private and public investment such as feed-in tariffs for solar projects) into cleantech of $243 billion in 2010, but comment that the 'market is in flux' in the face of challenging financial conditions, with big variations in investment across geographies and technologies.[141] China receives most investment, followed by the USA, with countries in Europe struggling to balance financial commitments to developing clean technologies against managing national deficit.

In a sense, given the argument above that innovation is about having the right networks in the economy and then commissioning specific technologies, it could be argued that scaling back direct subsidies and grants, regardless of the purpose, is not troublesome if innovative forces were coming from elsewhere. However, a look at recent data seems to imply that this is not the case. In fact, the UK is at risk of falling behind in this area, having been seen as a country that was catching up in the last decade.

Since green technology is still in its very early stage, when Knightian uncertainty is highest, venture capital funding is focused on some of the safer bets rather than on the radical innovation which is so needed to allow the sector to transform society in the ways that the 20-20-20 policies are hoping.[142] Ghosh and Nanda claim that it is virtually only public sector funds that are currently funding the riskiest and the most capital intensive projects in green technology — the ones in the upper right hand corner in figure 9.[143] Venture capital funding is concentrating virtually only on some of the areas in the bottom right. This is highly problematic since the early stage of the sector means that by definition many of the needed developments are still capital intensive so unless the government makes a mark, these important areas will remain underdeveloped.

Figure 9 **Sub-sectors of venture capital within clean energy**



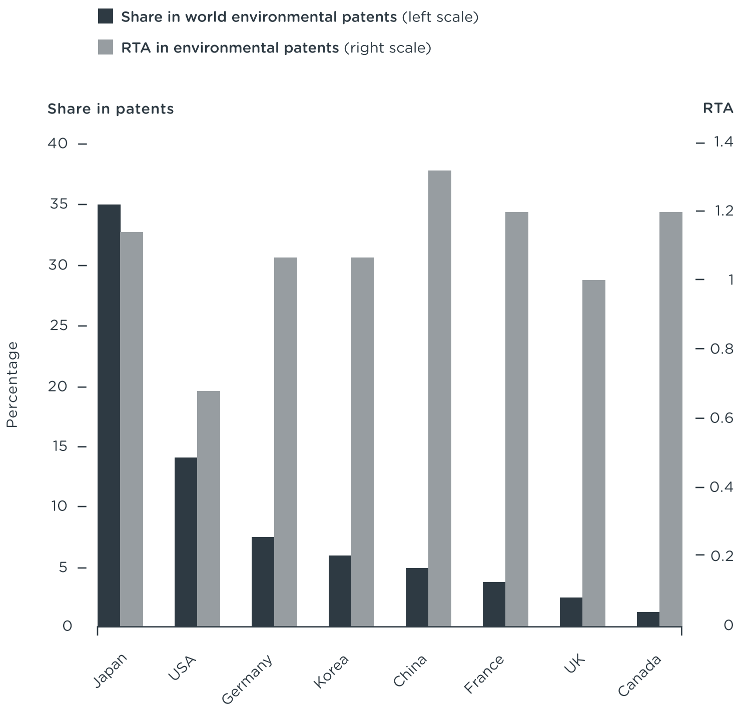
Source: Ghosh and Nanda [144]

Historically the UK had been viewed as one of the most innovative countries in clean technologies starting since 2000, despite its role as a laggard in the early 1990s,[145] with investments in cleantech infrastructure and R&D increasing in response to government commitments of £405 million to cut down the carbon emissions by around one-third by 2020.[146] Compared with other countries the UK's cleantech innovation sourced more from smaller firms and academia so would seem generally supportive of an environment for venture capital investment.[147] However, while venture capital investment in cleantech in the USA recovered during 2010, venture capital investment activity in the UK was at its lowest level since 2003.[148]

Although global investment may be approaching recent record levels, Ernst and Young's analysis of the total investment (all sources) required to achieve the EU 2020 target, of 20 per cent of energy supplied by renewable sources by 2020, estimated an annual investment gap of €35 billion for European member states to find each year.[149] Such large investment requirements are required at a time when venture capitalists begin to realise the limitations of their investment models. For instance in 2009 observers noted venture capital funds shifting focus to funding cleantech investments with less than two-year pay-back periods. More incremental innovations that deal with energy efficiency appear to be given priority over the cutting edge bio-fuels or advanced solar technologies.[150] Analysis of the investment activity of UK firms funded by venture capitalists found two-thirds of firms had no patents, suggesting investors had not primarily focused on radical innovations, and that those investors supporting patenting firms tended to be larger, with a wide coverage of industries, suggesting a lack of specialisation.[151]

Figure 10 shows that Japan is currently the global leader in environmental technology patents, possibly because its corporate culture and chronically low interest rates promote an unusually long payback horizon compared with the Anglo-American norm. The right-hand side of the scale is the country's share in world environmental patents relative to the share of the country in total world patents; an RTA greater than one measures specialisation in environmental patents. So, for example, Japan's high global share in environmental patents is combined with an internal specialisation in environmental technologies; China has also patented more in environmental technologies than other sectors, although this is not (yet) enough to achieve global dominance.

Figure 10 **Countries' share of and specialisation in environmental patents (2001-2005)**



Source: WIPO152

Note: RTA is the share of the country in world environmental patents relative to the share of the country in total world patents; RTA > 1 measures specialisation in environmental patents.

Likewise Ghosh and Nanda highlight that venture capitalists are increasingly targeting incremental innovations in established technologies to improve energy efficiency, moving away from more radical forms of innovation for energy production.[153] The preferences for familiar technology and quick payback add to fears of a renewed 'dash for gas' as the most likely way for the UK to try meeting its emissions reduction commitments, even though this will add to dangers of energy insecurity and of sharply rising costs when gas reserves begin to deplete.

The financial and technological risks of developing alternative forms of energy production have been too high for venture capital to support, owing to the size and duration of technical risks beyond traditional proof of concept. For instance, even if proof of concept is achieved, it may not be feasible to produce at the scale required for energy production. The financial risks of supporting a firm to reach the stage where technology is scalable is too great for most venture capital funds. In this sense the absence of liquid IPO markets for cleantech firms restricts the technology that venture capitalists can support. Ghosh and Nanda suggest that, in the absence of an appropriate investment model, venture capital may struggle to provide the types of rapid development of radical innovation solutions required.[154]

The conclusion that might follow is that the government needs to be commissioning the development of the riskiest technologies. But this is not happening either. The main initiative of the Coalition Government is to establish a green investment bank to provide seedcorn funding for green technologies. It is based on the notion that the green revolution can be led privately, simply 'incentivised' by the state. This is wrong (no other tech revolution has occurred this way), and the current amounts being discussed are too insignificant to make any difference. The green investment bank initiative does not learn from previous revolutions in the importance of active state- led investments, allowing the country to 'be first' and hence reap future increasing returns. China is building one power station a week and Britain is fiddling with play money.

Improving the UK's ageing energy infrastructure will require massive investments. The proposed green investment bank could help to get important projects off the drawing board. However, as the cash for it is dependent on selling off strategic assets in difficult market conditions, it will take many months or even years before the fund is able to make a meaningful difference. And the current figures are peanuts. However, expanded and broadened, the green investment bank could grow into a strategic investment bank, like the European Investment Bank or Germany's Kreditanstalt für Wiederaufbau. Those have a proven track record of promoting infrastructure development and returning a profit for the taxpayer—the UK has always lacked a comparable source of long-term finance, and would gain from developing one. If it took more of an innovation focus than the European Investment Bank and Kreditanstalt für Wiederaufbau, it could become a new type of public-sector strategic finance institution. This would be helpful particularly to get large scale projects off the ground. But it would not necessarily provide the incentive for the high risk innovative breakthroughs to occur in the first place.

The inability of the UK to lead the world in the development of green technologies is the result not of the lack of a green investment bank to provide seedcorn finance but of an underdeveloped ecology of networks and government procurement systems designed to wrench technological progress out of that system. Once the breakthroughs have occurred, finance will need to be found to transform our existing infrastructure to reduce its environmental impact. But that is about implementation, rather than innovation.

A clue to what is required is again found in the USA, where government funded initiatives are busy building on their understanding of what has worked in previous technological revolutions.

Obama's greentech initiative

With the passage of the American Recovery and Reinvestment Act by the current Obama administration, the Department of Energy (DOE) was allocated tens of billions of dollars to develop alternative energy technologies and to alter existing infrastructure to reduce energy waste. This recent initiative represents an enormous expansion of government spending to shape innovation in the civilian economy, exactly the opposite of what is being argued in the UK, where the debate continues to be the static one between 'picking winners' and 'creating the right conditions' while being ineffectual in allowing the UK to become leader in any sector.

In addition, the current US administration created a new programme, ARPA-E, which is modelled specifically on the DARPA model 'to focus on "out of the box" transformational research that industry by itself cannot or will not support due to its high risk but were success would provide dramatic benefits for the nation'.[155] The agency is charged with bringing forth a new, exciting direction to energy research that 'will attract many of the U.S.'s best and brightest minds—those of experienced scientists and engineers, and especially, those of students and young researchers, including persons in the entrepreneurial world'.[156] Using the DARPA model ARPA-E's organisation is 'flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programmes that do not prove to be as promising as anticipated'.[157] With a focus on network expansion, the agency was also established to develop a 'new tool to bridge the gap between basic energy research and development/industrial innovation'.[158]

In 2009 the DOE awarded $377 million in funding for 46 new multi-million dollar energy frontier research centers (EFRCs) located at universities, national laboratories, non-profit organisations, and private firms throughout the US. Spanning a period of five years, the DOE has committed $777 million to this initiative.[159] The scale of funding signals that the DOE is committed to moving products through technological maturity and into the stage of broad production and deployment. Hundreds of millions of dollars is being allocated to firms (through matching funds and loan programmes) by the DOE to support the development of productive facilities for solar panels, batteries for electric cars, biofuel projects, along with programmes focusing specifically on advancing the deployment of photovoltaics on homes and businesses.[160]

The recommendation to the UK government is clear. To maintain a lead in cleantech and greentech, the Government should be commissioning the development of break-through technologies in areas where it has a comparative advantage, creating a pull factor for innovations to flow through. There is no avoiding the fact that this will cost money, which is why we also propose that resources be diverted from flat subsidies of R&D activity and small businesses, which may or may not lead to innovation and growth.

6 Final thoughts on risk-taking in innovation: who gets the return?

This pamphlet has attempted to highlight the active role that the state has played in generating innovation-led growth. As has been argued, this has entailed very risky investments – speculation for 'creative destruction'.

In finance, it is commonly accepted that there is a relationship between risk and return. However, in the innovation game, this has not been the case. Risk-taking has been a collective endeavour while the returns have been much less collectively distributed. Often, the only return that the state gets for its risky investments are the indirect benefits of higher tax receipts that result from the growth that is generated by those investments. Is that enough?

There is indeed lots of talk of partnership between the government and private sector, yet while the efforts are collective, the returns remain private. Is it right that the National Science Foundation did not reap any financial return from funding the grant that produced the algorithm that led to Google's search engine?[161] Can an innovation system based on government support be sustainable with such a system of rewards? The lack of knowledge in the public domain about the central entrepreneurial role that government plays in the growth of economies worldwide, beyond Keynesian demand management and 'creating the conditions' for growth, is currently putting the successful model in major danger.

This contrast is well depicted by the example offered in Vallas, Kleinman and Biscotti:

A new pharmaceutical that brings in more than $1 billion per year in revenue is a drug marketed by Genzyme. It is a drug for a rare disease that was initially developed by scientists at the National Institutes of Health. The firm set the price for a year's dosage at *upward of $350,000. While legislation gives the government the right to sell such government-developed drugs at 'reasonable' prices, policymakers have not exercised this right. The result is an extreme instance where the costs of developing this drug were socialized, while the profits were privatized. Moreover, some of the taxpayers who financed the development of the drug cannot obtain it for their family members because they cannot afford it.* [162]

The socialised generation and privatised commercialisation of biopharmaceutical—and other—technologies could be followed by withdrawal of the state, if private companies used their profits to reinvest in research and further product development. The state's role would then be limited to that of initially underwriting radical new discoveries, until they are generating profits that can fund ongoing discovery. But private-sector behaviour suggests that public institutions cannot pass the R&D baton in this way. And that the state's role cannot be limited to that of planting seeds that can be subsequently relied on to grow freely.

Many of the problems being faced today by the Obama administration are indeed due to the fact that US taxpayers are virtually unaware of how their taxes foster innovation and growth in the USA, and that corporations that have made money from innovation that has been supported by the government are neither returning a significant portion of the profits to the government nor investing in new innovation.[163] They are sold the idea that this growth occurs as a result of individual 'genius', to Silicon Valley 'entrepreneurs', to venture capitalists, to what they think is a 'weak' state compared with the European system. These battles are also being played out in the UK where it is argued that the only way for the country to achieve growth is for it to be privately led and for the state to go back to its minimal role of ensuring the rule of law.

An implication of this pamphlet is that the only way to make growth 'fairer' and for the gains to be better shared is for economists, policy makers, and the general public to have a broader understanding of which agents in society take part of the fundamental risk-taking that is necessary to bring on innovation-led growth. As has been argued, risk-taking and speculation are absolutely necessary for innovations to occur. The real Knightian uncertainty that innovation entails is in fact the reason that the private sector, including venture capital, often shies away from it.

Understanding the dynamics of innovation must be brought in line with our understanding of dynamics of inequality. These areas of economic thought have been separated since David Ricardo's study of the effect of mechanisation on the wage–profit frontier — distribution. Recently, the relationship has come back in vogue with studies on how skill-biased technological change affects wages. This work explains inequality through how wages are affected by technologies like IT that favour skilled over unskilled labour by increasing its relative productivity and, therefore, its relative demand and wages. Inequality is thus explained here as a result of how economic incentives shaped by relative prices, the size of the market, and institutions create biases in factors of production, which then affect their returns.[164] While this work provides some important insights, it does not explain many dynamics of inequality, including why within a sector, the different agents that take part of production and innovation reap such different benefits from the innovation. Inequality is indeed just as high within sectors as it is between.[165]

The idea of an entrepreneurial state suggests that one of the core missing links between growth and inequality (or to use the words of the EC 2020 strategy, between 'smart' and 'inclusive' growth) lies in a wider identification and understanding of the agents that contribute to the risk-taking required for that growth to occur. Bank bonuses, for example, should not logically be criticised using arguments against the greed and underlying inequality that is produced (even though these generate powerful emotions). Rather they should be argued against by attacking the underlying logical foundation on which they stand.

The received wisdom is that bankers take on very high risks, and when those risks reap a high return, they should in fact be rewarded — they deserve it. The same logic is used to justify the exorbitantly high returns that powerful shareholders have earned in the last decades, which has been another prime source of increasing inequality. The logic here is that shareholders are the biggest risk takers since they only earn the returns that are left over once all the other economic actors are paid (the 'residual' if it exists, once workers and managers are paid their salaries, loans paid off, and so on). Hence when there is a large residual they are the proper claimant—they could in fact have earned nothing since there is no guarantee that there will be a residual.

However an understanding of risk that gives credit to the role of the public sector in innovative activities immediately makes it logical for there to be a more collective distribution of the rewards that should exist. Central to this question is the need to better understand how the division of 'innovative labour' maps into a division of rewards.[166] The innovation literature has provided many interesting insights on the former, for example the changing dynamic between large firms, small firms, government research and individuals in the innovation process.[167] But there is very little understanding on the latter. Yet, as Lazonick has argued, governments and workers also (and perhaps more so) invest in the innovation process without guaranteed returns.[168]

The critical point is the relation between those who bear risk in contributing their labour and capital to the innovation process and those who appropriate rewards from the innovation process. As a general set of propositions on the risk–reward nexus, when the appropriation of rewards outstrips the bearing of risk in the innovation process, the result is inequity; when the extent of inequity disrupts investment in the innovation process, the result is instability; and when the extent of instability increases the uncertainty of the innovation process, the result is a slowdown or even decline in economic growth.[169] A major challenge for the UK and for Europe 2020 is to put in place institutions to regulate the risk–reward nexus so that it supports equitable and stable economic growth.

To achieve this it is essential to understand innovation as a collective process, involving an extensive division of labour that can include many different types of contributors. As a foundation for the innovation process, the state typically makes investments in physical and human infrastructure that individual employees and business enterprises would be unable to fund because of a combination of the amount of fixed costs that investment in innovation requires and the degree of uncertainty that such investment entails. The state also subsidises the investments that enable individual employees and business enterprises to participate in the innovation process. Academic researchers often interact with industry experts in the knowledge-generation process. Within industry there are research consortia that may include companies that are otherwise in competition with one another. There are also user–producer interactions in product development within the value chain. And within the firm's hierarchical and functional division of labour, there is the integration into the processes of organisational learning of the skills and efforts of large numbers of people involved in the hierarchical and functional division of labour.

Identification of who bears risk cannot be achieved by simply asserting that shareholders are the only contributors to the economy who do not have a guaranteed return—a central, and fallacious, assumption of financial economics based on agency theory. Indeed, in so far as public shareholders simply buy and sell shares, and are willing to do so because of the ease with which they can liquidate these portfolio investments, they may make little if any contribution to the innovation process and bear little if any risk of its success or failure. In contrast, governments may invest capital and workers may invest labour (time and effort) in the innovation process without any guarantee of a return commensurate with their investments. For the sake of innovation, we need social institutions that enable these risk-bearers to reap the returns from the innovation process, if and when it is successful.

Conclusion

A core lesson of this pamphlet is the need to develop a new industrial policy which learns from the past experiences in which the state has played a leading, entrepreneurial, role in achieving innovation-led growth. State-funded organisations (mainly decentralised ones such as DARPA, SBIR and so on) have been fundamentally involved in generating radically new products and processes, which have changed the way that businesses operate and citizens live — transforming economies forever, from the internet revolution to the biotech revolution to what (it is hoped) will be the greentech revolution. It has also been argued that a core way to tackle smart and inclusive growth together is to ensure that the gains from innovation are just as collective as the risk-taking underlying it is.

In seeking innovation-led growth, it is fundamental to understand the important roles that both the public and private sector can play. This requires not only understanding the different ecologies between the public and private sector, but especially rethinking *what it is that the public is bringing to that ecology*. The assumption that the public sector can at best incentivise private sector led innovation (through subsidies, tax reductions, carbon pricing, green investment banks and so on) — a claim being propagated heavily in the UK, especially but not only in the face of the recent crisis and ensuing deficits — fails to account for the many examples in which the leading entrepreneurial force came from the state rather than from the private sector.

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The prevailing opinion on public spending is that the state must be cut back to make room for entrepreneurship and innovation, to prevent the public sector 'crowding out' the private sector. This draws on the belief that the private sector is dynamic, innovative and competitive, in contrast to the sluggish and bureaucratic public sector.

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