Chapter 1

FROM CRISIS IDEOLOGY TO THE DIVISION OF INNOVATIVE LABOUR

Governments have always been lousy at picking winners, and they are likely to become more so, as legions of entrepreneurs and tinkerers swap designs online, turn them into products at home and market them globally from a garage. As the revolution rages, governments should stick to the basics: better schools for a skilled workforce, clear rules and a level playing field for enterprises of all kinds. Leave the rest to the revolutionaries.

Economist (2012)

Across the globe we are hearing that the State has to be cut back in order to foster a post-crisis recovery. The assumption is that, with the State in the backseat, we unleash the power of entrepreneurship and innovation in the private sector. The media, business and libertarian politicians draw from this convenient contrast, and feed into the dichotomy of a dynamic, innovative and competitive 'revolutionary' private sector versus a sluggish, bureaucratic, inertial, 'meddling' public sector. The message is repeated so much so that it is accepted by the many as a 'common sense' truth, and has even made many believe that the 2007 financial crisis, which soon precipitated into a full blown economic crisis, was caused by public sector debt, rather than the truth.

And the language used has been forceful. In March 2011, UK prime minister David Cameron promised to take on the 'enemies of enterprise' working in government, which he defined as the 'bureaucrats in government departments' (Wheeler 2011). The rhetoric fits in with the UK 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 – with the justification that such 'freedom' from the State's influence will reinvigorate such services. The terms used, such as 'free' schools (the equivalent of charter schools in the USA) imply that by freeing schools from the heavy hand of the State, they will be both more interesting to students and also run more efficiently.

The increasing percentage of public services, across the globe, that are being 'outsourced' to the private sector, is usually done using precisely this 'efficiency' argument. Yet a proper look at the real cost savings that such outsourcing provides – especially taking into account the lack of 'quality control' and absurd costs that ensue – is almost never carried out. The recent scandal where the security for London's 2012 Olympics was outsourced to a company called G4S, which then failed due to utter incompetence to deliver, meant that the British Army was called in to provide security during the Olympics. While the managers of the company were 'reprimanded' the company today is still making profits and outsourcing remains on the rise. Examples where outsourcing is resisted, such as the BBC's choice to build the Internet platform for its broadcasting, the iPlayer, in-house has meant that it has been able to keep the BBC a dynamic innovative organization, that continues to attract top talent, retaining its high market share in both radio and TV – what public broadcasters in other countries can only dream of.

The view of the State as enemy of enterprise is a point of view found constantly in the respected business press, such as the *Economist*, which often refers to government as a 'Hobbesian Leviathan' which should take the back seat (*Economist* 2011a). Their prescription for economic growth includes focusing on creating freer markets and creating the right conditions for new ideas to prosper, rather than taking a more activist approach (*Economist* 2012). And in a recent special issue on the green revolution, the magazine explicitly made the case, as quoted in the beginning of this chapter, that while the government should 'stick to the basics', such as funding education and research, the rest should be left to the 'revolutionaries', i.e. businesses. Yet as will be argued in Chapters 4–8, this revolutionary spirit is often hard to find in the private sector, with the State having to take on the greatest areas of risk and uncertainty.

When not lobbying the State for specific types of support, established business lobby groups – in areas as diverse as weapons, medicine and oil – 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 conservative 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' (Ambler and Boyfield 2010, 4). In the USA, supporters of the Tea Party movement are united by a desire to limit State budgets and promote free markets. Big pharmaceutical companies, which, as we will see in Chapter 3, are some of the biggest beneficiaries of publicly funded research, constantly argue for less regulation and 'meddling' in what they claim is a very innovative industry.

And in the Eurozone

And, in the eurozone, it is today argued that all the ills of the 'peripheral' EU countries like Portugal and Italy come from having a 'profligate' public sector, ignoring the evidence that such countries are characterized more by a stagnant public sector which has not made the kind of strategic investments that the more successful 'core' countries, such as Germany, have been making for decades (Mazzucato 2012b).

The power of the ideology is so strong that history is easily fabricated. A remarkable aspect of the financial crisis that began in 2007 was that even though it was blatantly caused by excessive private debt (mainly in the US real estate market), many people were later led to believe that the chief culprit was public debt. It is true that public sector debt (Alessandri and Haldane 2009) rose drastically both due to the government-funded bank bailouts and reduced tax receipts that accompanied the ensuing recession in many countries. But it can hardly be argued that the financial crisis, or the resulting economic crisis, was caused by public debt. The key issue was not the amount of public sector spending but the type of spending. Indeed, one of the reasons that Italy's growth rate has been so low for the last 15 years is not that it has been spending too much but that it has not been spending enough in areas like education, human capital and R&D. So even with a relatively modest pre-crisis deficit (around 4 per cent), its debt/GDP ratio kept rising because the rate of growth of the denominator in this ratio remained close to zero.

While there are of course low-growth countries with large public debts, the question of which causes which is highly debatable. Indeed, the recent controversy over the work of Reinhart and Rogoff (2010) shows just how heated the debate is. What was most shocking, however, from that recent debate was not only the finding that their statistical work (published in what is deemed the top economics journal) was done incorrectly (and recklessly), but how quickly people had believed the core result: that debt above

90 per cent of GDP will necessarily bring down growth. The corollary became the new dogma: austerity will necessarily (and sufficiently) bring back growth. And yet there are many countries with higher debt that have grown in a stable fashion (such as Canada, New Zealand and Australia – all ignored by their results). Even more obvious is the point that what matters is surely not the aggregate size of the public sector, but what it is spending on. Spending on useless paperwork, or kickbacks, is surely not the same thing as spending on making a healthcare system more functional and efficient, or spending on top-quality education or ground-breaking research that can fuel human capital formation and future technologies. Indeed, the variables that economists have found to be important for growth – such as education and research and development – are expensive. The fact that the weakest countries in Europe, with high debt/GDP ratios, have been spending very little in these areas (thus causing the denominator in this ratio to suffer) should not come as a surprise. Yet the austerity recipes that are currently being forced on them will make this problem only worse.

And this is where there is a self-fulfilling prophecy: the more we talk down the State's role in the economy, the less able we are to up its game and make it a relevant player, and so the less able it is to attract top talent. Is it a coincidence that the US Department of Energy, which is the lead spender on R&D in the US government and one of the lead spenders (per capita) on energy research in the OECD, has been able to attract a Nobel Prize–winning physicist to run it? Or that those countries with much less ambitious plans for government organizations are more susceptible to crony-type promotions and little expertise within ministries? Of course the problem is not simply of 'expertise', but the ability to attract it is an indicator of the importance it is given within public agencies in a given country.

State Picking Winners vs. Losers Picking the State

We are constantly told that the State should have a limited role in the economy due to its inability to 'pick winners', whether the 'winners' are new technologies, economic sectors or specific firms. But what is ignored is that, in many of the cases that the State 'failed', it was trying to do something much more difficult than what many private businesses do: either trying to extend the period of glory of a mature industry (the Concorde experiment or the American Supersonic Transport project), or actively trying to launch a new technology sector (the Internet, or the IT revolution).

Operating in such difficult territory makes the probability of failure much higher. Yet by constantly bashing the State's ability to be an effective and innovative agent in society, not only have we too easily blamed the State for some of its failures, we have also not developed the accurate metrics needed to judge its investments fairly. Public venture capital, for example, is very different from private venture capital. It is willing to invest in areas with much higher risk, while providing greater patience and lower expectations of future returns. By definition this is a more difficult situation. Yet the returns to public versus private venture capital are compared without taking this difference into account.

Ironically, the inability of the State to argue its own position, to explain its role in the winners that have been picked (from the Internet to companies like Apple) has made it easier to criticize it for its occasional failures (e.g. the Supersonic Transport project). Or even worse, it has responded to criticism by becoming vulnerable and timid, easily 'captured' by lobbies seeking public resources for private gain, or by pundits that parrot the 'myths' about the origins of economic dynamism.

In the late 1970s capital gains taxes fell significantly following lobbying efforts on behalf of the US venture capital industry (Lazonick 2009, 73). The lobbyists argued before the government that venture capitalists had funded both the Internet and the early semiconductor industry, and that without venture capitalists innovation would not happen. Thus the same actors who rode the wave of expensive State investments in what would later become the dot.com revolution, successfully lobbied government to reduce their taxes. In that way the government's own pockets, so critical for funding innovation, were being emptied by those who had depended on it for their success.

Furthermore, by not being confident of its own role, government has been easily captured by the myths describing where innovation and entrepreneurship come from. Big Pharma tries to convince government that it is subject to too much regulation and red tape, while it is simultaneously dependent on government-funded R&D. Small business associations have convinced governments in many countries that they are underfunded as a category. Yet in many countries, they receive more support than the police force, without providing the jobs or innovation that helps justify such support (Hughes 2008; Storey 2006). Had the State better understood how its own investments have led to the emergence of the most successful new companies, like Google, Apple and Compaq, it would perhaps mount a stronger defence against such arguments.

But the State has not had a good marketing/communications department. Imagine how much easier President Barack Obama's fight for US national healthcare policy would have been if the US population knew the important role that the US government had in funding the most radical new drugs in the industry (discussed in Chapter 3). This is not 'propaganda' – it's raising awareness about history of technology. In health, the State has not 'meddled' but created and innovated. Yet the story told, and unfortunately believed, is one of an innovative Big Pharma and a meddling government. Getting the (complex) history right is important for many reasons. Indeed, the high prices charged for drugs, whether they are subsidized by the State or not, are justified by the industry with their alleged 'high R&D costs'. Uncovering the truth not only helps government policies to be better designed but also can help the 'market' system work better.

The emphasis on the State as an entrepreneurial agent is not of course meant to deny the existence of private sector entrepreneurial activity, from the role of young new companies in providing the dynamism behind new sectors (e.g. Google), to the important source of funding from private sources like venture capital. The key problem is that 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 (US) or Cambridge (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: tipping the balance in favour of the market would 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 (Battelle 2005)? 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? How many people realize that many of the most innovative young companies in the US were funded not by private venture capital but by *public* venture capital, such as that provided by 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 worry of 'picking winners'. What we have instead is a case for a targeted, proactive, *entrepreneurial* State, one able to take risks and create a highly networked system of actors that harness the best of the private sector for the national good over a medium- to long-term time horizon. It is the State acting as lead investor and catalyst which sparks the network to act and spread knowledge. The State can and does act as creator, not just facilitator of the knowledge economy.

Arguing for an entrepreneurial State is not 'new' industrial policy because it is in fact what has happened. As Block and Keller (2011, 95) have explained so well, the industrial directives of the State are 'hidden' primarily to prevent a backlash from the conservative right. Evidence abounds of the State's pivotal role in the history of the computer industry, the Internet, the pharmaceutical-biotech industry, nanotech and the emerging green tech sector. In all these cases, the State dared to think – against all odds – about the 'impossible': creating a new technological opportunity; making the initial large necessary investments; enabling a decentralized network of actors to carry out the risky research; and then allowing the development and commercialization process to occur in a dynamic way.

Beyond Market Failures and System Failures

Economists willing to admit the State has an important role have often argued so using a specific framework called 'market failure'. From this perspective the fact that markets are 'imperfect' is seen as the exception, which means that the State has a role to play – but not a very interesting one. Imperfections can arise for various reasons: the unwillingness of private firms to invest in areas, like basic research, from which they cannot appropriate private profits because the results are a 'public good' accessible to all firms (results of basic R&D as a positive externality); the fact that private firms do not factor in the cost of their pollution in setting prices (pollution as a negative externality); or the fact that the risk of certain investments is too high for any one firm to bear them all alone (leading to incomplete markets). Given these different forms of market failure, examples of the expected role of the State would include publicly funded basic research, taxes levied on polluting firms and public funding for infrastructure projects. While this framework is useful, it cannot explain the 'visionary' strategic role that government has played in making these investments. Indeed, the discovery of the Internet or the emergence of the nanotechnology industry did not occur because the private sector wanted something but could not find the resources to invest in it. Both happened due to the vision that the government had in an area that had not yet been fathomed by the private sector. Even after these new technologies were introduced by government, the private sector still was too scared to invest. Government even had to support the commercialization of the Internet. And it took years for private venture capitalists to start financing biotech or nanotech companies. It was – in these and many such cases – the State that appeared to have the most aggressive 'animal spirits'.

There are many counterexamples that would characterize the State as far from an 'entrepreneurial' force. Developing new technologies and supporting new industries is not the only important role of the State, after all. But admitting the instances where it has played an entrepreneurial role will help inform policies, which are too often based on the assumption that at most the State's role is to correct market failures or facilitate innovation for the 'dynamic' private sector. The assumptions that all the State has to do is to 'nudge' the private sector in the right direction; that tax credits will work because business is eager to invest in innovation; that removing obstacles and regulations is necessary; that small firms – simply due to their size – are more flexible and entrepreneurial and should be given direct and indirect support; that the core problem in Europe is simply one of 'commercialization' – are all myths. They are myths about where entrepreneurship and innovation come from. They have prevented policies from being as effective as they could be in stimulating the kinds of innovation that businesses would not have attempted on their own.

The Bumpy Risk Landscape

As will be explained in more detail in the next chapter, innovation economists from the 'evolutionary' tradition (Nelson and Winter 1982) have argued that 'systems' of innovation are needed so that new knowledge and innovation can diffuse throughout the economy, and that *systems* of innovation (sectoral, regional, national) require the presence of dynamic links between the different *actors* (firms, financial institutions, research/education, public sector funds, intermediary institutions), as well as horizontal links *within* organizations and institutions (Lundvall 1992; Freeman 1995). What has been ignored even in this debate, however, is the exact role that each actor realistically plays in the 'bumpy' and complex *risk landscape*. Many errors of current innovation policy are due to placing actors in the wrong part of this landscape (both in time and space). For example, it is naïve to expect venture capital to lead in the early and most risky stage of any new economic sector today (such as clean technology). In biotechnology, nanotechnology and the Internet, venture capital arrived 15–20 years *after* the most important investments were made by public sector funds.

In fact, history shows that those areas of the risk landscape (within sectors at any point in time, or at the start of new sectors) that are defined by high capital intensity and high technological and market risk tend to be avoided by the private sector, and have required great amounts of public sector funding (of different types), as well as public sector vision and leadership to get them off the ground. The State has been behind most technological revolutions and periods of long-run growth. This is why an 'entrepreneurial State' is needed to engage in risk taking and the creation of a new vision, rather than just fixing market failures.

Not understanding the role that different actors play makes it easier for government to get 'captured' by special interests which portray their role in a rhetorical and ideological way that lacks evidence or reason. While venture capitalists have lobbied hard for lower capital gains taxes (mentioned above), they do not make their investments in new technologies on the basis of tax rates; they make them based on perceived risk, something typically reduced by decades of prior State investment. Without a better understanding of the actors involved in the innovation process, we risk allowing a symbiotic innovation system, in which the State and private sector mutually benefit, to transform into a parasitic one in which the private sector is able to leach benefits from a State that it simultaneously refuses to finance.

Symbiotic vs. Parasitic Innovation 'Ecosystems'

It is now common to talk about innovation 'systems' as 'ecosystems'. Indeed it seems to be on the tongue of many innovation specialists and policymakers. But how can we be sure that the innovation ecosystem is one that results in a *symbiotic* relationship between the public and private sector rather than a *parasitic* one? That is, will increased investments by the State in the innovation ecosystem cause the private sector to invest less, and use its retained earnings to fund short-term profits (via practices like 'share buybacks'), or more, in riskier areas like human capital formation and R&D, to promote long-term growth?

Usually a question like this might be framed in terms of the 'crowding-out' concept. Crowding out is a hypothesis in economics that says that the danger of State investment is that it uses up savings that could have been used by the private sector for its own investment plans (Friedman 1979). Keynesians have argued against the idea that State spending crowds out private investment, by emphasizing that this would only hold in a period of full resource utilization, a state that hardly ever occurs. However, the issues raised in this book present a different view: that an entrepreneurial State invests in areas that the private sector would not invest even if it had the resources. And it is the courageous risk-taking visionary role of the State which has been ignored. Business investment is mainly limited not by savings but by its own lack of courage (or Keynesian 'animal spirits') – the 'business as usual' state of mind. Indeed, firm-level studies have shown that what drives entry behaviour into industries (companies deciding to move into one particular sector) are not existing profits in that sector but projected technological and market opportunities (Dosi et al. 1997). And such opportunities are linked to the amount of State investment in those areas.

But what if that potentially courageous aspect of the private sector is diminished precisely because the public sector fills the gap? Rather than framing the question in terms of 'crowding out', I believe we must frame it in such a way that results in building private–public partnerships that are more symbiotic and less parasitic. The problem is not that the State has financed too much innovation, making the private sector less ambitious. It is that policymakers have not been ambitious enough to demand that such support be part of a more collaborative effort in which the private sector also steps up to the challenge. Instead big R&D labs have been closing, and the R of the R&D spend has also been falling, with BERD (business expenditure on R&D) falling in many countries like the UK (Hughes and Mina 2011). While State spending on R&D and business spending tend to be correlated (the former ups the game for the latter), it is important that policymakers be more courageous – not only in agreeing to 'fund' sectors but also in demanding that businesses in those sectors increase their own stakes and commitment to innovation. A recent study by MIT claims that the current absence in the US of corporate labs like Xerox PARC (which produced the graphical user interface technology that led to both Apple's and Windows' operating systems) and Bell Labs – both highly co-financed by government agency budgets – is one of the reasons why the US innovation machine is under threat (MIT 2013).

The problem is also evidenced in industries, like pharmaceuticals, where there is a trend of increasing public sector investments in R&D, while private sector spending is decreasing. According to Lazonick and Tulum (2012), the National Institutes of Health (NIH) have spent more than $300 billion over the last decade ($30.9 billion in 2012 alone), and become more involved in the D component of R&D, meaning they absorb greater costs of drug development (such as through clinical trials), while private pharmaceutical companies[1] have been spending less on R&D overall, with many shutting down R&D labs altogether. Of course the total R&D spent may be increasing, because the development (D) part is getting increasingly expensive. But this hides the underlying issue. While some analysts have justified the decreasing expenditure on research in terms of low productivity of R&D (increased expenditures, not matched by increased discoveries), others, like Angell (1984, ex-editor of the *New England Journal of Medicine*), have been more explicit in blaming Big Pharma for not doing its share. She argues that for decades the most radical new drugs have been coming out of public labs, with private pharma concerned more with 'me too' drugs (slight variations of existing drugs) and marketing (see Chapter 3 for more details). And in recent years, CEOs of large pharma companies have admitted that their decision to downsize – or in some cases eliminate – their R&D labs is due to their recognition that in the 'open' model of innovation most of their research is obtained by small biotech firms or public labs (Gambardella 1995; *China Briefing* 2012). Big Pharma's focus is thus turned to working with such alliances, and 'integrating' knowledge produced elsewhere, rather than funding R&D internally.

Financialization

One of the greatest problems, which we return to in Chapter 9, has been the way in which such reductions in spending on R&D have coincided with an increasing 'financialization' of the private sector. While causality may be hard to prove, it cannot be denied that at the same time that private pharma companies have been reducing the R of R&D, they have been increasing the amount of funds used to repurchase their own shares – a strategy used to boost their stock price, which affects the price of stock options and executive pay

1 From now on 'pharma' will refer to pharmaceutical companies, and Big Pharma the top international pharma companies.

linked to such options. For example, in 2011, along with $6.2 billion paid in dividends, Pfizer repurchased $9 billion in stock, equivalent to 90 per cent of its net income and 99 per cent of its R&D expenditures. Amgen, the largest dedicated biopharma company, has repurchased stock in every year since 1992, for a total of $42.2 billion through 2011, including $8.3 billion in 2011. Since 2002 the cost of Amgen's stock repurchases has surpassed the company's R&D expenditures in every year except 2004, and for the period 1992–2011 was equal to fully 115 per cent of R&D outlays and 113 per cent of net income (Lazonick and Tulum 2011). The fact that top pharma companies are spending a decreasing amount of funds on R&D at the same time that the State is spending more – all while increasing the amount they spend on share buybacks, makes this particular innovation ecosystem much more parasitic than symbiotic. This is not the 'crowding out' effect: this is free-riding. Share buyback schemes boost stock prices, benefitting senior executives, managers and investors that hold the majority of company stock. Boosting share prices does not create value (the point of innovation), but facilitates its extraction. Shareholders and executives are thus 'rewarded' for riding the innovation wave the State created. In Chapter 9 I look more closely at the problem of value extraction and ask whether and how some of the 'returns' from innovation should be returned to the employees and State that are also key contributors and stakeholders in the innovation process.

Unfortunately the same problem seems to be appearing in the emerging clean technology sector. In 2010, the US American Energy Innovation Council (AEIC), an industry association, asked the US government to increase its spending on clean technology by three times to $16 billion annually, with an additional $1 billion given to the Advanced Research Projects Agency – Energy (Lazonick 2011c). On the other hand, companies in the council have together spent $237 billion on stock repurchases between 2001 and 2010. The major directors of the AEIC come from companies with collective 2011 net incomes of $37 billion and R&D expenditures of approximately $16 billion. That they believe their own companies' enormous resources are inadequate to foster greater clean technology innovation is indicative of the State's role as the first driver of innovation or of their own aversion to taking on risks – or both.

The problem of share buybacks is not isolated but rampant: in the last decade, S&P 500 companies have spent $3 trillion on share buybacks (Lazonick 2012). The largest repurchasers (especially in oil and pharmaceuticals) claim that this is due to the lack of new opportunities. In fact in many cases the most expensive (e.g. capital-intensive) investments in new opportunities such as medicine and renewable energy (investments with high market and technological risk) are being made by the public sector (GWEC 2012). This raises the question of whether the 'open innovation' model is becoming a dysfunctional model. As large companies are increasingly relying on alliances with small companies and the public sector, the indication is that large players invest more in short-run profit gains (through market gimmicks) than long-run investments. I return to this question in Chapters 9 and 10.

Now that 'new' industrial policy is back on the agenda, with many nations trying to 'rebalance' their economies away from finance and towards 'real' economy sectors, it is more important than ever to question exactly what this rebalancing will entail (Mazzucato 2012a). While some have focused on the need for different types of private–public partnerships that can foster innovation and economic growth, what I'm arguing here (and will focus on more in Chapters 8 and 9) is that we need to be more careful to build the type of partnerships which increase the stakes of all involved, and which do not lead to similar problems that the financialization of the economy led to: socialization of risk, privatization of rewards.

The work of Rodrik (2004) has been particularly important in highlighting the need to rethink public and private sector interactions, and to focus more on processes rather than policy outcomes. His focus is on the types of exploratory processes that allow the public and private sectors to *learn* from each other, especially the opportunities and constraints that each face (Rodrik 2004, 3). He takes this to mean that the problem is not which types of tools (R&D tax credits vs. subsidies) or which types of sectors to choose (steel vs. software), but how policy can foster self-discovery processes, which will foster creativity and innovation. While I agree with Rodrik's general point about the need to foster exploration and trial and error (and this is in fact a core tenet of the 'evolutionary theory of economic change', which I review in the next chapter), I believe that the history of technological change teaches us that choosing particular sectors in this process is absolutely crucial. The Internet would never have happened without it being forcefully 'picked' by DARPA, and the same holds for nanotechnology which was picked by the NSF and later by the National Nanotech Initiative (both discussed in Chapter 4). And, most importantly, the green revolution will not take off until it is firmly picked and backed by the State (as will be discussed in Chapters 6 and 7).

Coming back to Keynes's (1926) fundamental point about the essential role of government, what we need to ask is: how can horizontal and vertical tools and policies 'make things happen' that would not have otherwise? The problem with R&D tax credits is not that they are specific policy tools, but they have been designed wrongly and do not increase private investments in R&D. Evidence shows that targeting R&D labour rather than R&D income (through credits) is much better for that (Lockshin and Mohnen 2012). And the problems with throwing money at a particular area like life sciences is not that it was 'picked' but that it was not first transformed to be less dysfunctional before it was supported. When so many 'life science' companies are focusing on their stock price rather than on increasing their side of the R in R&D, simply subsidising their research will only worsen the problem rather than create the type of learning that Rodrik (2004) rightly calls for.

Chapter 2

TECHNOLOGY, INNOVATION AND GROWTH

You can see the computer age everywhere but in the productivity statistics.
Solow (1987, 36)

In a special report on the world economy, the *Economist* (2010a) stated:

> A smart innovation agenda, in short, would be quite different from the one that most rich governments seem to favor. 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.

This view is also espoused by some 'progressive' academics, who argue that the State is limited to creating 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. (Lent and Lockwood 2010, 7)

This is the view that asks little of government other than correcting market failures – such as through investment in basic science, education and infrastructure. The 'appropriate' role of the State is not a new debate, but it is one that benefits from a broader understanding of the academic literature on the role of innovation in creating economic growth.

Over two hundred and fifty 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 'trust' (a moral code) between actors, were nurtured and protected (Smith 1904 [1776]). Smith's 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 organize production and distribution without coercion by the State.

The path-breaking work of Karl Polanyi (who had a doctorate in law but is considered an important economist) has instead shown how the notion of the market as self-regulating is a myth unsupported by the historical origins of markets: 'The road to the free market was opened and kept open by an enormous increase in continuous, centrally organized and controlled interventionism' (Polanyi 2001 [1944], 144). In his view, it was the State which imposed the conditions that allowed for the emergence of a market-based economy. Polanyi's work has been revolutionary in showing the myth of the State vs. market distinction: the most capitalist of all markets, i.e. the national market, was forcefully 'pushed' into existence by the State. If anything it was the more local and international markets, which have pre-dated capitalism, that have been less tied to the State. But capitalism, the system that is usually thought of being 'market' driven, has been strongly embedded in, and shaped by, the State from day one (Evans 1995).

John Maynard Keynes believed that capitalist markets, regardless of their origin, need constant regulation because of the inherent instability of capitalism. Keynes contended that the stability of capitalism was dependent on keeping all of the four categories of spending (aggregate demand) in GDP in balance with one another: business investment (I), government investment (G), consumption spending (C), and net exports (X−M). A key source of extreme volatility was found in private business investment. The reason it is so volatile is that far from being a simple function of interest rates or taxes,[1] it is subject to 'animal spirits' – the gut-instinct assumptions made about future growth prospects in an economy or specific sector by investors (Keynes 1934). In his view, this uncertainty constantly creates periods of under- or overinvestment, causing severe fluctuations in the economy that are compounded by the multiplier effect. According to Keynes, unless private investment is balanced by increased government spending, declines in consumption and investment will lead to market crashes and depressions, which were indeed a frequent fact of life before Keynes's ideas found their way into post–Second World War economic policies.

Keynesians have argued forcefully for the importance of using government spending to boost demand and stabilize the economy. Economists, inspired by the work of Joseph Schumpeter (1883–1950), have gone further, asking that the government also spend on those specific areas that increase a nation's capacity for innovation (reviewed further below). Support for innovation can take the form of investments made in R&D, infrastructure, labour skills, and in direct and indirect support for specific technologies and companies.

On the left side of the political spectrum, investments into programme areas that increase productivity have been less fashionable than simple spending on welfare state institutions such as education or health. But welfare state institutions cannot survive without a productive economy behind it that generates the profits and tax receipts that can fund such entitlements (Nordhaus and Shellenberger 2011; Atkinson 2011). While progressive redistributional policies are fundamental to ensuring that the results of economic growth are fair, they do not in themselves cause growth. Inequality can hurt growth but equality does not alone foster it. What has been missing from much of the Keynesian left is a growth agenda which creates and simultaneously redistributes the riches. Bringing together the lessons of Keynes and Schumpeter can make this happen. This is why the last chapters of this book focus on the need to better understand why innovation and inequality can go hand in hand, and how this requires realigning the risks and rewards of economic growth to put a stop to one of the unfortunate consequences of modern-day capitalism: risks that are socialized and rewards that are privatized, not just in the financial sector but also in manufacturing.

In general, there has been a lack of connection between Keynesian fiscal spending and Schumpeterian investments in innovation. The lack of connection is due in no small part to Keynes advocating 'useless government'; that is, that State intervention into an economy was based primarily on temporary spending that could occur in any manner (even if it was hiring workers to dig up treasure hidden in an

1 The insensitivity of investment to taxes is the reason that the 1980s-style 'supply-side' economics had little effect on investment and hence GDP, and a large effect on income distribution (no 'trickle-down' effect).

abandoned coal mine)[2]. Indeed, this is the micro–macro connection that is still missing in modern-day economics. Yet empirically the connection is there. Not only is it true that productive investments generate growth, but that when spending is more 'directed' towards, say, the IT revolution in the 1980s and 1990s, and perhaps the green revolution in the years to come, the Keynesian multiplier effect is stronger. As Tassey argues:

> ...the highest order problem is the long-term inadequacy of productivity enhancing investments (technology, physical, human and organizational capital). Increasing the demand for housing does have a multiplier effect on that industry's supply chain, but this effect pales compared to the leverage from investment in technology for hardware and software that drive productivity in many industries. Equally important, the jobs created by a technology-driven supply chain are much higher paying – but, they must be sustained over entire technology life cycles. (2012, 31)

Keynes 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.[3] But in order to understand the dynamics of such

2 This refers to Keynes's provocative statement that: 'If the Treasury were to fill old bottles with bank-notes, bury them at suitable depths in disused coal-mines which are then filled up to the surface with town rubbish, and leave it to private enterprise on well-tried principles of laissez-faire to dig the notes up again (the right to do so being obtained, of course, by tendering for leases of the note-bearing territory), there need be no more unemployment and, with the help of repercussions, the real income of the community, and its capital wealth, would probably become a good deal greater than it actually is' (1936, 129). Keynes was referring to the fact that in times of underutilized capacity, even such apparently useless actions could get the economic engine going. However, the point of this book is to highlight how the State has, even in the boom periods such as the 1990s, provided important directionality in its spending, increasing the animal spirits of the private sector by investing in areas that the private sector fears.

3 Indeed, the application of Keynesian analysis to the theory of economic crises, with a proper understanding of finance in this dynamic, was developed by Hyman Minsky. Minsky (1992) focused on the *financial* fragility of capitalism by highlighting the way that financial markets cause crises to occur. Financial bubbles followed cycles of credit expansion, and exaggerated growth expectations were followed by retraction, causing bubbles to burst and asset prices to collapse. Like Keynes, he believed that the State had a crucial role in preventing this vicious cycle and stabilizing growth.

investments, it is fundamental to better understand different perspectives on the theory of economic growth first, and then to establish the role of technology and innovation in driving that economic growth.

Technology and Growth

While growth and the wealth of nations has been the lead concern of economists since Adam Smith, in the 1950s it was shown by Abramovitz (1956) and Solow (1956) that conventional measures of capital and labour inputs could not account for 90 per cent of economic growth in an advanced industrialized country such as the United States. 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 driving those views.

For years, economists have tried to model growth. Neoclassical economics developed its first growth model in the work of Harrod and Domar (Harrod 1939; Domar 1946), 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. Included in 'other things' was technological change.

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

While increases in K and L would cause movements *along* the production function (curve), exogenous (unexplained) changes in technical change would cause an upward shift in the curve (allowing both K and L to be used more productively). When Solow discovered that 90 per cent of variation in economic output was not explained by capital and labour, he called the residual 'technical change'. Abramovitz, who knew much more about the social conditions that support technical change than Solow, famously called the residual a 'measure of our ignorance' (Abromovitz 1956).

If the underlying model was found to be so deficient that it could not explain 90 per cent of the dependent variable it was describing, then it should have been thrown out and a new model developed. This was indeed what many, such as Joan Robinson (Harcourt 1972) had been arguing for decades. Robinson and others were highly critical of the production function framework. Instead of getting rid of the bad old model, however, technical change was simply added into it. Solow's theory (1956) became known as 'exogenous growth theory' because the variable for technical change was inserted exogenously, as a time trend A (t) (similar to population growth):

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

As economists became 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, as well as investment in human capital formation (Grossman and Helpman 1991). 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 new ideas were treated as endogenous to the firm, not as part of the institutional organization required to transform ideas into products. Nevertheless, the increasing emphasis on the relationship between technical change and growth indirectly led government policymakers to focus on the importance of investments in technology and human capital to foster growth. The result was *innovation-led growth* policies to support the knowledge economy, a term used to denote the greater importance of investing in knowledge creation in promoting economic competitiveness (Mason, Bishop and Robinson 2009). Studies that showed a direct relationship between the market value of firms and their innovation performance as measured by R&D spending and patent success supported these policies (Griliches, Hall and Pakes 1991).

From Market Failures to System Failures

In their ground-breaking *An Evolutionary Theory of Economic Change*, Nelson and Winter (1982) argued that the production function framework

(exogenous or endogenous) was in fact the wrong way to understand technological change. Building on the work of Joseph Schumpeter (1949, 1942 [2003]), they argued for an 'evolutionary theory' of production (and economic change), which delved inside the 'black box' of the production function in order to understand how innovation occurs and affects competition and economic growth. In this approach, there is no assumption of 'representative agents' (as in standard growth theory) 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 coevolution 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.

Rather than relying on laws of 'diminishing returns', which lead to a unique equilibrium, and assumptions about the 'average' firm, this approach focuses on dynamic increasing returns to scale (from the dynamics of learning by doing, as well as the kind of 'path-dependent' dynamics described by David 2004), and on different types of processes that lead to persistent differences between firms that do not disappear in the long run. The question is then: which firms survive and grow? Selection does not always lead to 'survival of the fittest' both due to the effect of increasing returns (allowing first-mover advantages which then 'stick') and also to the effects of policies which might favour certain types of firms over others. It might also be that selection dynamics in product markets and financial markets are at odds (Geroski and Mazzucato 2002b).

But most importantly, in this perspective innovation is firm specific, and highly uncertain. The 'evolutionary' and Schumpeterian approach to studying firm behaviour and competition has led to a 'systems of innovation' view of policy where what matters is understanding the way in which firms of different type are embedded in a system at sectoral, regional and national levels. In this systems view, it is not the quantity of R&D that matters, but how it is distributed throughout an economy, often reflective of the crucial role of the State in influencing the distribution (Freeman 1995; Lundvall 1992). Schumpeterian economists criticize 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, which cannot be modelled with a normal (or any other) probability distribution that is implicit in endogenous growth theory, where R&D is often modelled using game theory (Reinganum 1984). By highlighting the strong uncertainty underlying technological innovation, as well as the very strong feedback effects that exist between innovation, growth and market structure, Schumpeterians emphasize the 'systems' component of technological progress and growth.[4] 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' (Freeman 1995), or 'the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge' (Lundvall 1992, 2).

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 nor micro, but more meso, where individual firms are seen as part of broader network of firms with whom they cooperate and compete. The system of innovation can be interfirm, regional, national or global. From the meso perspective the network is the unit of analysis (not the firm). The network consists of customers, subcontractors, infrastructure, suppliers, competencies or functions, and the links or relationships between them. The point is that the competencies that generate innovation are part of a collective activity occurring through a network of actors and their links or relationships (Freeman 1995).

The causation that occurs in the steps taken between basic science, to large-scale R&D, to applications, and finally to diffusing innovations is not 'linear'. Rather, innovation networks are full of feedback loops existing between markets and technology, applications and 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, quality control and effective demand are just as important. Furthermore, it is

4 The emphasis on heterogeneity and multiple equilibria requires this branch of theory to rely less on assumptions of representative agents (the average company) and unique equilibria, so dear to neoclassical economics. Rather than using incremental calculus from Newtonian physics, mathematics from biology (such as distance from mean replicator dynamics) are used, which can explicitly take into account heterogeneity, and the possibility of path dependency and multiple equilibria. See M. Mazzucato, *Firm Size, Innovation and Market Structure: The Evolution of Market Concentration and Instability* (Northampton, MA: Edward Elgar, 2000).

better able to recognize the serendipity and uncertainty that characterizes the innovation process. It is useful for understanding the rise and fall of different economic powers in history. For example, it explains the rise of Germany as a major economic power in the nineteenth century, as a result of State-fostered technological education and training systems. It also explains the rise of the United States as a major economic power in the twentieth century as a result of the rise of mass production and in-house R&D. The United States and Germany became economic powers for different reasons but what they had in common was attention to developing systems of innovation rather than a narrow focus on raising or lowering R&D expenditures.

The general point can be illustrated by contrasting the experience of Japan in the 1970s and 1980s with that of the Soviet Union (Freeman 1995). The rise of Japan is explained as new knowledge flowing through a more horizontal economic structure consisting of the Ministry of International Trade and Industry (MITI), academia and business 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 R&D funding was spread across a wider variety of economic sectors, not just those focused on the military and space as was the case in the Soviet Union. In Japan, there was a strong integration between R&D, production and technology import activities at the enterprise level, whereas in the Soviet Union there was separation. Crucially, the Soviet Union did not have, or permit, business enterprises to commercialize the technologies developed by the State. Japan had strong user–producer linkages, which were nonexistent in the Soviet system. Japan also encouraged innovation with incentives provided to management and the workforce of companies, rather than focusing mainly on the ministries of science. Johnson (1982) argues that the 'Japanese miracle' was in essence the presence of a Developmental State,[5] or, the coordination of the Japanese

5 Chalmers Johnson (1982) was one of the first authors to conceptualize the 'Developmental State', when he analysed the State-led industrialization of Japan. Johnson argued that, in contrast to a (supposedly) hands-off, regulatory orientation in the US, the Japanese 'Developmental State' directly intervened in the economy, with strong planning promoted by a relatively independent State bureaucracy, which also promoted a close business–government relationship, whereby governmental support, protection and discipline resulted in a private elite willing to take on risky enterprises. Subsequent elaborations of the 'Developmental State' concept can be found in, among others, Wade (1990), Chang (1993), Evans (1995), Woo-Cumings (1999) and Chang and Evans (2000). Recently, contrary

economy through deliberate and targeted industrial policy instituted by MITI. Yet, Lazonick (2008, 27–8) adds that, 'the contribution of the developmental state in Japan cannot be understood in abstraction from the growth of companies' (such as Toyota, Sony or Hitachi); aside from the Japanese State's public support for industry, 'it was the strategy, organization, and finance, internal' to Japan's leading firms that transformed them 'from entrepreneurial firms into innovative firms' and that 'made them successful' in challenging the competitiveness of the world's most advanced economies. Equally important were the lessons learned by Japanese people that went abroad to study Western technologies for their companies, and relationships between those companies to US firms. These companies benefitted from the lessons of the US 'Developmental State', and then transferred that knowledge to Japanese companies which developed internal routines that could produce Western technologies and eventually surpass them. Japanese conglomerates were among the first foreign companies to license the transistor from AT&T (Bell Labs) in the early 1950s. As a result key connections were made with Western companies such as GE, IBM, HP and Xerox. Particular sectors like electronics were targeted forcefully, and the organizational innovation adopted by Japanese firms embodied a flexible 'just-in-time' and 'total quality' production system (which was a necessity to avoid unused capacity and waste, and deal with the lack of natural resources in Japan) that was applied to a wide variety of economic sectors with great success.

Table 1 compares the Japanese and Soviet systems of innovation. It is important in this context to highlight that the MITI's industrial policy was beyond the 'picking winners' idea that many opposed to industrial policy cite today. Japan's approach 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 and targeted manner. The Japanese model, which was an alternative to the more vertical 'Fordist' model of production in the US, characterized by rigidity and tense relations between trade unions and management, caused a more solid flow of knowledge and competencies in the economy that provided an advantage to the horizontally structured and flexible Japanese firms. While on opposite ends of the political spectrum, the production model in the USSR and the USA were equally 'rigid', allowing the Japanese model to supersede both.

to Johnson's (1982) original view, Block (2008) showed the existence of an often 'hidden' Developmental State in the US, a view similarly espoused by Reinert (2007) and Chang (2008).

Table 1. 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 technology import at enterprise level	Separation of R&D, production and technology import, weak institutional linkages
Strong user–producer and subcontractor network linkages	Weak or nonexistent linkages between marketing, production, and procurement
Strong incentives to innovate at enterprise level that involve 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). Note: Gross domestic expenditures on research and development (GERD) are all monies expended on R&D performed within the country in a given year.

Regional systems of innovation focus on the cultural, geographical and institutional proximity that create and facilitate transactions between different socioeconomic actors. Studies focusing on innovative milieu such as industrial districts and local systems of innovation have demonstrated that conventions and specific socioinstitutional 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.

The State's role is not just to create knowledge through national labs and universities, but also to mobilize resources that allow knowledge and innovations to diffuse broadly across sectors of the economy. It does this by rallying existing innovation networks or by facilitating the development of new ones that bring together a diverse group of stakeholders. However, having a national system of innovation that is rich in horizontal and vertical networks is not sufficient. The State must also lead the process of industrial development, by developing strategies for technological advance in priority areas.

This version of the State's role has been accepted in a consensus between multiple countries that are attempting to catch up with most technologically advanced economies. 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 industrialization. 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 (Amsden 1989). In states that were late to industrialize, the State itself led the industrialization drive. It took on developmental functions, for example by targeting certain sectors for investment, placed barriers to foreign competition until such time as companies in the targeted sectors were ready to export, and then provided assistance finding new export markets for companies. In Japan, for example, Johnson (1982) illustrates how the MITI worked to coordinate Japanese firms in new international markets. This occurred through investments made in particular technologies (picking winners), and the creation of specific business strategies meant to win particular domestic and international markets. Furthermore, the Japanese State coordinated the finance system through the Bank of Japan as well as through the Fiscal Investment Loan Program (funded by the postal savings system).

Chang (2008) offers similar illustrations for South Korea and other recently emerged economies. China has engaged in a targeted industrialization strategy too, only joining the World Trade Organization once its industries were ready to compete, rather than as part of an International Monetary Fund–backed industrialization strategy. The Chinese strategy showed the weaknesses of the Washington Consensus on development, which denied the State the active role that it played in the development of major industrialized nations such as the United States, Germany and the United Kingdom.

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?

Myths about Drivers of Innovation and Ineffective Innovation Policy

The fact that economics was putting so much emphasis on innovation in the growth process caused policymakers, since the 1980s, to begin paying much more attention to variables like R&D and patents as a predicator of innovation and therefore of economic growth. For example, the European Union's Lisbon Agenda (2000) and its current Europe 2020 strategy (EC 2010) set a target for 3 per cent of the EU's GDP to be invested in R&D, along with other policies meant to encourage the flow of knowledge between universities and business – and a stronger link between financial markets and innovative firms of different size.

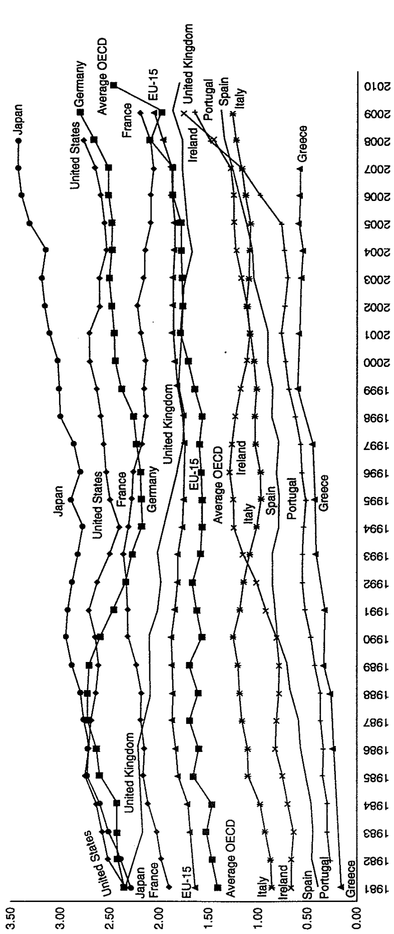
While countries within the OECD continue to differ greatly in their R&D spending (Figure 1 below), what is interesting is that those European countries that have suffered the most from the financial crisis, which later turned into a sovereign debt crisis, were also countries that have the lowest R&D expenditures. This of course does not mean that it is their low R&D intensity that caused their problems, but it is surely related. In the case of Italy, in fact, its high debt/GDP ratio (120 per cent in 2011) was not due to too much spending but spending in the wrong places. Its deficit for many years was relatively mild, at around 4 per cent. But its lack of investment in productivity-enhancing R&D and human capital development meant that its growth rate remained below the interest rate that it paid on its debt, thus making the numerator of the debt/GDP ratio grow more than the denominator. The fact that EU countries spend so differently on areas that create long-run growth is one of the reasons that they were each affected so differently by the economic crisis. The numerous approaches to growth were a reason that there was such little solidarity when it came time to help each other out. German 'falks' feel that German tax money should not be used to bail out the Greeks. However, they err in thinking that the Greeks are spendthrifts. The reforms that are required to make the European project work require not only 'structural' reforms (increasing the propensity to pay tax, labour market reform etc.) but also, and especially, increases in public and private sector investment in research and human capital formation that produce innovation. Getting support for such policies is virtually impossible under the current new 'fiscal compact', which limits spending by European member states to 3 per cent of GDP without differentiating between the spending that, through innovation and capital investments, can lead to future growth.

While low spending on R&D is a problem throughout much of the European 'periphery', it is also true that if a country has lower than average R&D spending, this is not necessarily a problem if the sectors that the country specializes in are not sectors in which innovation occurs necessarily through R&D (Pierrakis 2010). For example, the UK specializes in financial services, construction and creative industries (such as music) – all with relatively low needs for basic R&D. And there are many industries, especially in the service sector, that do no R&D at all. 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 for R&D/GDP (which characterized both the European Commission's Lisbon Agenda and the current EC 2020 agenda). 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 from the economy, even if that process undermines the conditions for innovation in other industries (Mazzucato and Lazonick 2010)?

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 made by governments and businesses that are also required to generate superior economic performance.

The National Systems of Innovation perspective described above highlights the important role of intermediary institutions in diffusing the knowledge created by new R&D throughout a system. An even greater problem with R&D-based innovation policies is the lack of understanding of the complementary assets that must be in place at the firm level that make it possible for technological innovations to reach the market, e.g. infrastructure or marketing capabilities.

Figure 1. Gross R&D spending (GERD) as a percentage of GDP in OECD, 1981–2010



Source: OECD (2011).

There have been many myths created around innovation-led growth. These have been based on wrong assumptions about the key drivers of innovation, from R&D, to small firms, venture capital and patents. A brief discussion of these follows. I call them 'myths', though they are perhaps more clearly called false assumptions leading to ineffective innovation policy.

Myth 1: Innovation is about R&D

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. While the systems of innovation literature referred to above has argued strongly against the linear model of innovation, much innovation policy still targets R&D spending at the firm, industry and national levels. Yet there are very few studies which prove that innovation carried out by large or small firms actually increases their growth performance – that is, the macro models on innovation and growth (whether 'new growth' theory models or the 'Schumpeterian' models) do not seem to have strong empirical 'micro foundations' (Geroski and Mazzucato 2002a). Some company-level studies have found a positive impact of R&D on growth (Geroski, Machin and Toker 1992; 1996, Yasuda 2005) while others found no significant impact (Almus and Nerlinger 1999; Bottazzi et al. 2001; Lööf and Heshmati 2006). 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 assets needed, R&D becomes only a cost (Brouwer, Kleinknecht and Reijnen 1993; Freel and Robson 2004).

It is thus fundamental to identify the company-specific conditions that must be present to allow spending on R&D to positively affect growth. These conditions will no doubt differ between sectors. Demirel and Mazzucato (2012), 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. Innovation policies in this sector must thus target not only R&D but also different attributes of firms. Coad and Rao (2008) found that only the fastest-growing firms reap benefits from their R&D spending (the top 6 per cent identified in NESTA's 2009 report 'The Vital 6%'). Mazzucato and Parris (2011) find that the relationship between R&D spending and fast-growing firms only holds in specific periods of the industry life-cycle, when competition is particularly fierce.

Myth 2: Small is Beautiful

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 for employment), and hence that many different policies that target SMEs are needed to generate innovation and growth. Hughes (2008) has shown that in the UK SMEs received close to £9 billion in direct and indirect government support, which is more than the police force receives. Is this money well spent? The hype around small firms arises mainly from the confusion between size and growth. The most robust evidence available emphasizes not the role of small firms in the economy but to a greater extent the role of *young* high-growth firms. NESTA, for example, showed that the firms most important to growth in the UK have been the small number of fast-growing businesses that, between 2002 and 2008, generated the greatest employment increase in the country (NESTA 2011). And while many high-growth firms are small, many small firms are not high growth.[6] The bursts of rapid growth that promote innovation and create employment are often staged by firms that have existed for several years and grown incrementally until they reached a take-off stage. This is a major problem since so many government policies focus on 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, and increasingly a focus of policymakers, this is mainly a myth. While by definition small firms will create jobs, they will in fact also destroy a large number of jobs when they go out of business. Haltiwanger, Jarmin and Miranda (2010) find that there is indeed no systematic relationship between firm size and growth. 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 often less productive than large firms. Indeed recent evidence has suggested that some economies that have favoured small firms, such as India, have in fact

6 Not to mention the statistical effect of being small: while a one-person micro-enterprise that hires an additional employee will display a 100 per cent growth in employment, a 100,000 person enterprise that hires 1,000 employees will show 'only' a 1 per cent increase in employment. And yet, it is obvious which of these hypothetical firms contributes more to a decrease in unemployment at the macro-level.

performed worse. Hsieh and Klenow (2009), for example, suggest that 40–60 per cent of the total factor productivity (TFP) difference between India and the United States is due to misallocation of output to too many small and low-productivity SMEs in India. As most small start-up firms fail, or are incapable of growing beyond the stage of having a sole owner-operator, targeting assistance to them through grants, soft loans or tax breaks will necessarily involve a high degree of waste. While this waste is a necessary gamble in the innovation process (Janeway 2012), it is important to at least guide the funding process with what we know about 'high growth' innovative firms rather than some folkloristic notion of the value of SMEs as an aggregate category – which actually means very little.

Bloom and Van Reenen (2006) argue that small firms are less productive than large ones because they are less well managed and subject to provincial family favouritism. Furthermore, small firms have lower average wages, fewer skilled workers, less training, fewer fringe benefits and higher instances of bankruptcy. They argue that the UK has many family firms and a poor record of management in comparison with other countries such as the US and Germany (2006). Among other reasons, this is related to the fact that the tax system is distorted by giving inheritance tax breaks to family firms.

Some have interpreted as a result that it is high growth rather than size that matters, and that the best that government can do is to provide the conditions for growth through policies that foster innovation. Bloom and Van Reenen (2006) 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 barriers to entry and growth, among firms of all sizes, enforcing competition policy, and strongly resisting the lobbying efforts of larger firms and their agents'. 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 association between size and growth much more complex.

The policy implication is that 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 to hand out subsidies in the hope that innovation will follow. In an era where budget deficits are constraining available resources, this approach could yield significant taxpayer savings if, for example, direct transfers to firms that are given just because of the size of a company were ended, such as small business rate relief for smaller companies and inheritance tax relief for family firms (Schmidt 2012).

Myth 3: Venture Capital is Risk Loving

If the role of small firms and R&D is overstated by policymakers, 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-stage growth funding where the objective of venture capitalists is to earn a high return following a successful IPO, merger or acquisition of the company. Venture capital fills a funding void that exists for new firms, which often have trouble gaining credit from traditional financial institutions such as banks. Such firms 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 for new firms trying to form a new sector.

Risk capital is scarce in the seed stage of firm growth because there is a much higher degree of risk in this early phase, when the potential of the new idea and its technological and demand conditions are completely uncertain (see Table 2). The risk in later phases falls dramatically.

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

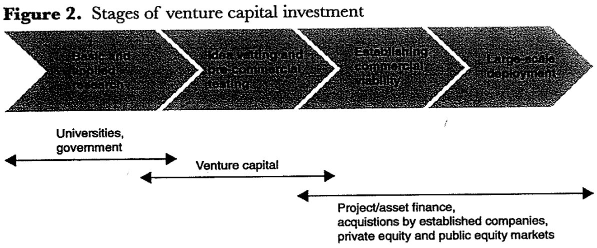
Figure 2 does not illustrate how time after time it has been public rather than privately funded venture capital that has taken the most risks. In the US, government programmes such as the Small Business Innovation Research (SBIR) programme and the Advanced Technology Program (ATP) within the US Department of Commerce have provided 20–25 per cent of total funding for early stage technology firms (Auerswald and Branscomb 2003, 232). Thus, government has played a

Table 2. 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 (2010).

Figure 2. Stages of venture capital investment



Source: Ghosh and Nanda (2010, 6).

leading role not only in the early stage research illustrated in Figure 2, but also in the commercial viability stage. Auerswald and Branscomb (2003) 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.

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

Although most venture capital funds are usually structured to have a life of ten years, they tend to prefer to exit much earlier than ten years because of the management fees and the bonuses earned for high returns. Early exits are preferred in order to establish a winning 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 3-to-5-year period (Ghosh and Nanda 2010). Although this is sometimes possible (e.g. Google), it is often not. 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 tolerance of failure. Venture capital has succeeded more in the US when it provided not only committed finance, but managerial expertise and the construction of a viable organization (Lazonick 2012).

The problem has been not only the lack of venture capital investment in the most critical early seed stage, but also its own objectives in the innovation process. This has been strongly evidenced in the biotech industry, where an increasing number of researchers have criticized the venture capital model of science, indicating that significant investor speculation has a detrimental effect on the underlying innovation (Coriat, Orsi and Weinstein 2003; Lazonick and Tulum 2011; Mirowski 2011). 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. It creates a need to question the role of venture capital in supporting the development of science and also its effect on the growth process. The increased focus on patenting and venture capital is not the right way to understand how risky and long-term innovations occur. Pisano (2006) in fact claimed that the stock market was never designed to deal with the governance challenges presented by R&D-driven businesses. Mirowski (2011, 208) describes the venture capital–backed 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.

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

An alternative view is presented in Janeway (2012) who argues that stock market speculation is necessary for innovation. However, what he describes as a semi-natural element of capitalism was instead a result of a hefty political process, of lobbying (Lazonick 2009). NASDAQ was put in place to provide a speculative market on which high-tech start-ups could be funded but also exit quickly. And without NASDAQ, launched in 1971, VC would not have emerged as a well-defined industry in the 1970s. The coevolution of VC and NASDAQ is a result of the policy space being 'captured'. Another element not emphasized in Janeway, is the degree to which the 'rewards' to VC have been disproportional to the risks taken. His own VC company, Warburg Pincus, made millions in a game that he admits was about entering after the State did the hard work. While he says that the period of speculation was necessary, he does not confront the issue of how VC was justified in capturing such high returns. And neither that VC is itself becoming one of its own worst enemies by being such adamant lobbyists for a lower public purse (via lower taxes), which will not be able to fund the future innovations for VC to piggyback on.

Myth 4: We Live in a Knowledge Economy – Just Look at all the Patents!

Similarly to the myth that 'innovation is about R&D', a misunderstanding exists in relation to the role of patents in innovation and economic growth. For example, when policymakers look at the number of patents in the pharmaceutical industry, they presume it is one of the most innovative 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. In ICT there has been a shift in the use of patents from the development and protection of proprietary technologies, resulting from in-house R&D, to cross-licensing in open systems, with the purpose of buying in technology (and the related patents) produced elsewhere (Chesbrough 2003; Grindley and Teece 1997). This has caused the R&D budgets of large companies, such as IBM, to fall at the same time that their patent numbers rose (Lazonick 2009, 88–9). Not recognizing these dynamics cause a focus on the number of patents to be misguided.

The exponential rise in patents, and the increasing lack of relationship this rise has had with actual 'innovation' (e.g. 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' (as opposed to inventions) of existing objects of study 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 spinoffs from university labs receiving 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 seeking to attract financing. All these factors have caused the number of patents to rise, with most of them being of little worth (e.g. very few citations received from other patents), and with most not resulting in a high number of innovations, e.g. new drugs in pharma (see Figure 5 in Chapter 3). Thus directing too much attention to patents, rather than to specific types of patents, such as those that are highly cited, risks wasting a lot of 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 for things like 'research tools' have caused the rate of innovation to fall rather than increase as it blocks the ability of science to move forward in an open exploratory way (Mazzoleni and Nelson 1998). The effect has been especially deleterious to the ability of scientists in the developing world to repeat experiments carried out in the developed world. Prevented from replicating results, they cannot build on those experiments with their own developments, thus hurting their ability to 'catch up' (Forero-Pineda 2006).

Notwithstanding the fact that most patents are of little value, and that patents play a controversial role in innovation dynamics, different government policies continue to assume that patents have a strong link to ongoing high-tech R&D and must be incentivized to create innovation-led growth. In October 2010, George Osborne (the UK's chancellor of the exchequer, a role equivalent of the minister of finance or secretary of the treasury in other countries) announced a 'patent box' policy beginning in 2013, which will 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 through tax policy. The same policy has recently been introduced in the Netherlands.

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 (Griffith et al. 2010).

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 or innovation itself. Furthermore, the authors maintain 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. Since international collaborations are increasingly common, there is no guarantee that the extra research that is incentivized will be conducted in the country introducing the policy.

Myth 5: Europe's Problem is all about Commercialization

It is often assumed that Europe's main disadvantage in innovation as compared to the US is its lack of capability for 'commercialization' (see Figure 2) which stems from problems with the 'transfer' of knowledge. In fact, EU problems don't come from poor flow of knowledge from research but from the EU firms' smaller stock of knowledge. This is due to the great differences in public and private spending on R&D. While in the US R&D/GDP is 2.6 per cent, it is only 1.3 per cent in the UK. In Italy, Greece and Portugal – the countries experiencing the worst effects of the eurozone crisis – R&D/GDP spending is less than 0.5 per cent (Mazzucato 2012b).

If the US is better at innovation, it isn't because university–industry links are better (they aren't), or because US universities produce more spinouts (they don't). It simply reflects more research being done in more institutions, which generates better technical skills in the workforce (Salter et al. 2000). Furthermore, US funding is split between research in universities and early stage technology development in firms. Getting EU universities to do both runs the risk of generating technologies unfit for the market.

Thus there is not a problem of research quality in universities in Europe, nor in the collaboration between industry and universities, which probably occurs more frequently in the UK than the US. Nor is there a problem in universities generating firms, which again occurs more frequently in Europe than in the US (although there are major concerns about the quality of the firms that are generated, Salter et al. 2000; Nightingale 2012). If European firms lack the ability to innovate then technology transfer policies are like pushing a piece of string.

More generally, in the economics of innovation literature, there is often talk of the '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 (2006) support the points made above by providing evidence that the reason for European weakness is not, as is commonly claimed, the lack of science parks or interaction between education and industry. It is a weaker system of scientific research and the presence of weaker and less innovative companies. 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.

An alternative view – often voiced – is that Europe lacks sufficiently speculative stock markets to induce VC investment (Janeway 2012). While there are surely problems with the European venture capital industry (Bottazzi and Da Rin 2002), and there is perhaps not an equivalent to NASDAQ, this view ignores how the overly speculative US model undermines innovation. The problem is that the ideology surrounding both the role of VC, the role of the stock market and innovation, and the analysis of where innovation comes from, has prevented a 'healthy balance' of speculation and investment to be sustainable over time.

Myth 6: Business Investment Requires 'Less Tax and Red Tape'

While there is a research component in innovation, there is not a linear relationship between research and development, innovation and economic growth. While it is important that the frontiers of science advance and that economies develop the nodes and networks that enable knowledge to be transferred between different organizations and individuals, it does not follow that subsidizing the activity of R&D per se within individual firms is the best use of taxpayers' money. Although it is common sense that there is a relationship between a decision to engage in R&D and its cost (see Myth 1), 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.[7] There is also a potential problem under the current R&D tax credit system, in many countries, that it does not hold firms accountable as to whether they have conducted new innovation that would not otherwise have taken place, or simply pursued 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. Recently, the Netherlands has introduced an R&D tax credit that targets not the income from R&D (easily fudged) but R&D workers – and this has been found to be more effective, creating the kind of 'additionality' that income-based R&D tax credits don't (Lockshin and Mohnen 2012).

More generally, as Keynes emphasized, business investment (especially innovative investment) is a function of 'animal spirits', the gut instinct of investors about future growth prospects. These are impacted to a greater extent not by taxes but by the strength of a nation's science base, its system of credit creation, and its quality of education and hence human capital. Tax cuts in the 1980s did not produce more investment in innovation; they only affected income distribution (increasing inequality). For this same reason, 'enterprise zones' which are focused almost exclusively on tax benefits and weakened regulation are not *innovation* zones. It would be best to save that money or to invest it in properly run science parks for which there is better evidence that innovation will follow (Massey, Quintas and Wield 1992).

It is important for innovation policy to resist the appeal for tax measures of different kinds – such as the patent box discussed above, or R&D tax credits – unless they are structured in such a way that will lead to investments in innovation that would not have happened anyway, and real evidence confirms it. Most of all, it is essential for policymakers to be wary of companies that complain about 'tax and red tape', when it is clear that their own global actions reflect a preference for areas of the world where the State is spending precisely in those areas that create confidence and 'animal spirits' regarding future growth possibilities.

This chapter has argued that many of the assumptions that underlie current growth policy should not be taken for granted. Over the last decade or so, policymakers searching for proxies for economic growth

7 See HMRC, *An Evaluation of R&D Tax Credits* (2010) for an example of this.

have looked to things they can measure such as R&D spending, patents, venture capital investment, and the number of small firms that are assumed to be important for growth. I 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.

Chapter 4

THE US ENTREPRENEURIAL STATE

...since its founding fathers, the United States has always been torn between two traditions, the activist policies of Alexander Hamilton (1755–1804) and Thomas Jefferson's (1743–1826) maxim that 'the government that governs least, governs best'. With time and usual American pragmatism, this rivalry has been resolved by putting the Jeffersonians in charge of the rhetoric and the Hamiltonians in charge of policy.

Erik Reinert (2007, 23)

Despite the perception of the US as the epitome of private sector–led wealth creation, in reality it is the State that has been engaged on a massive scale in entrepreneurial risk taking to spur innovation. In this chapter four key successful examples are given: the roles of DARPA (the US government's Defense Advance Research Project Agency), SBIR (Small Business Innovation Research), the Orphan Drug Act (the EU passed its own Orphan Drug Act in 2001, imitating the US act passed in 1983) and the National Nanotechnology Initiative. What they share is a proactive approach by the State to shape a market in order to drive innovation. The insight gained is that other than being an entrepreneurial society, a place where it is culturally natural to start and grow a business, the US is also a place where the State plays an entrepreneurial role, by making investments in radical new areas. The State has provided early stage finance where venture capital ran away, while also commissioning high-level innovative private sector activity that would not have happened without public policy goals backing a strategy and vision.

So far I have argued that while the level of technological innovation is integral to the rate of economic growth, there is no linear relationship between R&D spending, the size of companies, the 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 established between different individuals and organizations to enable knowledge to be shared and its boundaries to be pushed back.

This chapter attempts to illustrate that at the frontiers of knowledge, simply having a national 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 role does not necessarily have to take place at a national level (although it can) and should not only involve long-term subsidies to certain companies ('picking winners'). Rather the State, through its various agencies and laboratories, has the potential to disseminate new ideas rapidly. It can also 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.

The Defense Advanced Research Projects Agency (DARPA)

The role that military engagement has had for economic growth and development does not differentiate US history from other modern countries. But in the US, the experience of technological development necessary to win wars has provided strong lessons to those seeking to improve innovation policy.

The role of the State in the Defense Advanced Research Projects Agency (DARPA) model goes far beyond simply funding basic science. It is about targeting resources in specific areas and directions; it is about opening new windows of opportunities; brokering the interactions between public and private agents involved in technological development, including those between private and public venture capital; and facilitating commercialization (Block 2008; Fuchs 2010).

In contrast to the emphasis placed by market fundamentalists on Franklin D. Roosevelt's New Deal as the critical turning point in US economic history, Block (2008) argues that the Second World War was a more significant period for the development of innovation policies in the US. 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). The interagency collaborations led to the development of technologies such as computers, jet planes, civilian

nuclear energy, lasers and biotechnology (Block 2008). The way this was done was 'pioneered' by the Advanced Research Projects 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 book, engaged in developing critical initiatives across a broad range of technologies.[1] However, it was the government 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 US technological superiority in different sectors, mainly (but not only) those 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 occurring within the military.

After a Second World War victory that relied heavily on State-sponsored and -organized 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. The relationship between government and science was further strengthened by the Manhattan Project (the major scientific effort led by the US, with the UK and Canada, which led to the invention and use of the atomic bomb in the Second World War), as physicists instructed policymakers 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 (2011, 7), during this period an increased number of government workers took on a more direct role in advancing innovation, procuring additional researchers, encouraging researchers to solve specific problems, and requiring that those researchers meet specific objectives. The insight that followed was that this was something government could do for economic and civilian purposes, in addition to the traditional military function.

1 The literature refers to both ARPA and DARPA.

The launching of Sputnik in 1957 by the Soviets led to an eruption of panic among US policymakers, 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 twenty 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 (Block 2008).

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 many of the technologies later incorporated in the design of the personal computer were developed by DARPA-funded researchers (Abbate 1999).

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 (Block 2011). The rebellious group of scientists and engineers, often referred to as the 'traitorous eight', went on to form Fairchild Semiconductor, a new firm that advanced semiconductor technology and continued 'a process of economic fission that was constantly spinning off new economic challengers' (Block and Keller 2011a, 12–13). Lazonick (2009) adds that the spinoff culture ultimately began with Fairchild Semiconductor – and the firm owed nearly all of its growth to military procurement. The spinoff business model became viable and popular for technological advancement following the 1957 revolt, yet would not have been possible without State involvement and it functioning as a major early customer. A new paradigm emerged that resulted in innovative ideas moving from labs to market in far greater quantity.

Before this, government officials' leverage in generating rapid technological advancement was limited, as large defence firms still deflected the pressure and demands for innovation with the tremendous power they wielded. 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 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 recognized the potential this new innovation environment provided and were able to take advantage of it, focusing at first on new, smaller firms to which they could provide much smaller funds than was possible with the larger defence contractors. These firms recognized the need for ambitious innovation as part of their overall future viability. With small, newer firms engaged in real competition and as the spinoff model became more institutionalized, Block (2008) notes that large firms also had to get on board with this quest for rapid innovative breakthroughs. By taking advantage of this new environment, the government was able to play a leading role in mobilizing 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 maximize 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 by linking university researchers to entrepreneurs interested in starting a new firm; connecting start-up firms with venture capitalists; finding a larger company to commercialize the technology; or assisting in procuring a government contract to support the commercialization 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 US. 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. In a recent documentary, *Something Ventured, Something Gained*, for example, the role of the State is not mentioned once in the 85 minutes spent describing the development of Silicon Valley (Geller and Goldfine 2012).

Also, during the 1970s, the significant developments taking place in biotechnology illustrated to policymakers that the role of DARPA in the computer industry was not a unique or isolated case of success. The decentralized 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 (2008, 188) identifies the four key characteristics of the DARPA model:[2]

- 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. The agency can provide firms with assistance that goes well beyond research funding.
- Part of the agency's task is to use its oversight role to link ideas, resources and people in constructive ways across the different research and development sites.

2 Block uses this to characterize his concept of a 'developmental network state', which builds on the concept of the 'developmental state' discussed in footnote 5 on page 37.

The main focus is to assist firms in developing new product and process innovations. The key is that the government serves as a leader for firms to imitate, in 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. In so doing, the government is able to attract top minds – exactly the kind of expertise that generates the dynamism that government is often accused of not having. As mentioned in the forward, this is clearly a self-fulfilling prophecy, because a government under constant attack will not dare be confident and dynamic.

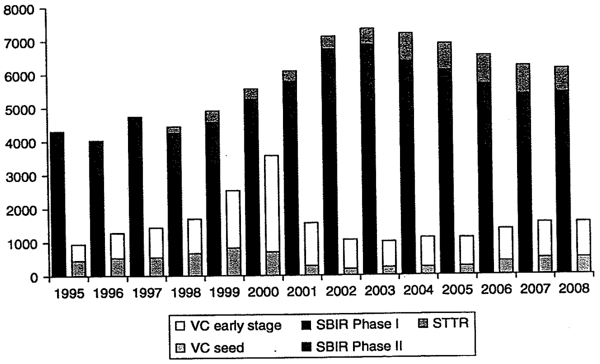
In Chapter 6, we will see how today ARPA-E, the newest agency within the US Department of Energy, is trying to do for 'green' what DARPA did for IT.

The Small Business Innovation Research (SBIR) 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 decentralized 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, setting up a consortium between the Small Business Administration and different government agencies like the Department of Defense, 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 small, independent, for-profit firms. As a result, the programme has provided support to a significant number of highly innovative start-up firms (Lerner 1999; Audretsch 2003).

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 organizations that were funded by state

Figure 9. Number of early stage and seed funding awards, SBIR and venture capital



Source: Block and Keller (2012, 15).

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 to 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 commercialization 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 it receives. Although the UK has, since 2001, attempted to copy its success, it has not been successful yet, as we will see in the next chapter.

Block (2011, 14) highlights the lack of visibility of the SBIR programme 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'. As indicated in the introduction of this book and again in the early stages of this chapter, this discrepancy poses an exceptional challenge; for both policymakers and the public who are engaged in economic debates as well as making efforts to address the current economic crises and while also paving the way for the future of innovation and development in the globalized world.

As can be seen in Figure 9, the role of the SBIR programme has not been diminishing, but increasing. Indeed, as venture capital has become increasingly short-termist, focused on pursuing capital gains, and seeking early exit through an IPO, the SBIR programme has had to step up its risk finance (Block and Keller 2012).

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 sliver 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, allowing them to advance to the position of becoming a major player in the biopharmaceutical 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 (Lazonick and Tulum 2011). Since the introduction of the ODA, 2,364 products have been designated as orphan drugs and 370 of these drugs have gained marketing approval (FDA, n.d.).

In addition to all of the conditions outlined by the ODA, Lazonick and Tulum (2011) draw attention to the fact that multiple versions of the same drug can be designated as 'orphan'. 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 ODA. 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, in 2010 Gleevec recorded global sales of $4.3 billion, thus confirming the point raised by Lazonick and Tulum (2011), that even when the market size for a drug is small, the revenues can be considerable.

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 benefitting. Some of the world's largest pharmaceutical firms such as Roche, Johnson & Johnson, GlaxoSmithKline and Pfizer, among others, have applied for orphan drug designation for their products. The National Organization for Rare Disorders, a non-profit public organization largely funded by the federal government, has been encouraging large pharmaceutical firms to share their redundant proprietary knowledge with smaller biotech firms through licensing deals, in an effort to develop drugs for orphan indications. Lazonick and Tulum (2011) explain the importance of the Orphan Drug Act by calculating the share of orphan drugs as a percentage of total product revenues for major biopharmaceutical firms. The financial histories of the six leading biopharmaceutical 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 (2011) show that orphan drugs are more numerous, their revenue growth began earlier, and many of them have greater 2007 sales (in dollars) than leading non-orphan drugs.

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. 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 summarized 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 [BP] 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. (2011, 18)

From this brief overview of these three examples of State-led support for innovation – DARPA, the SBIR programme and creation of a market for orphan drugs with the ODA – a general point can be drawn: the US has spent the last few decades using active interventionist policies to drive private sector innovation in pursuit of broad 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, yet it still 'picks winners'; there are 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, whether through supply-side policies (e.g. DARPA's information and brokerage support, strategic programmes and vision building) or through demand-side policies and funding for start up interventions (the SBIR programme and orphan drugs). 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 that facilitate commercial development. This is very far from current UK government policy approaches, which assume that the State can simply nudge the private sector into action.

The National Nanotechnology Initiative

The entrepreneurial role that the State can play 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 US. The types of investments and strategic decisions that the State has made have gone beyond simply creating the right infrastructure, funding basic research, and setting rules and regulations (as in a simple 'systems failure' approach).

Nanotechnology is very likely to be the next general purpose technology, having a pervasive effect on many different sectors and becoming the foundation of new economic growth. However, while this is commonly accepted now, in the 1990s it was not. Motoyama, Appelbaum and Parker (2011, 109–19) describe in detail how the US government has in fact been the lead visionary in dreaming up the possibility of a nanotech revolution – by making the 'against all odds' initial investments and by explicitly forming dynamic networks that bring together 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. 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 (2011, 111) 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.

The government's objective was to find the 'next new thing' to replace the Internet. After receiving 'blank stares' from the private sector, the key players (civil servants) in Washington convinced the US government to invest in the creation of a new research agenda, to prepare a set of budget options, and to provide a clear division of labour between different government agencies. But it had first to define nanotech. The President's Committee of Advisors on Science and Technology (PCAST) did so by arguing that the private sector could not expect to lead in developing applications of nanotech that were still 10 to 20 years away from commercial market viability (Motoyama, Appelbaum and Parker 2011, 113):

> 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.

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 business strategy) and that its rigid structures are not conducive to completing the R&D required. 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 relevant to the nanotechnology revolution (that draws on physics, chemistry, materials science, biology, medicine, engineering and computer simulation). As Block and Keller (2011a) discuss, government actions for cutting-edge new technologies have often had to remain veiled behind a 'hidden' industrial policy. The public sector activists driving nanotechnology had to continuously talk about a 'bottom-up' approach so that it would not seem to be an instance of 'picking winners' or choosing national champions. 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' (Motoyama, Appelbaum and Parker 2011, 112). 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 country that leads in discovery and implementation of nanotechnology will have great advantage in the economic and military scene for many decades to come' (Motoyama, Appelbaum and Parker 2011, 113).

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 it 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 decentralized through various State agencies (a total of 13, led by the NSF, but also involving the NIH, the Defense Department and the SBIR programme). Across these different agencies, currently the US government spends approximately $1.8 billion annually on the NNI.

Nanotechnology today does not yet create a major economic impact because of the lack of commercialization of new technologies. Motoyama, Appelbaum and Parker (2011) claim that this is due to the excessive investments made in research relative to the lack of investments in commercialization. They call for a more active government investment in commercialization. However, this raises the question, if government has to do the research, fund major infrastructure investments and also undertake the commercialization effort, what exactly 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 drag on the economic system, it has fostered innovation and dynamism in many important modern industries, with the private sector often taking a back seat. Ironically the State has often done so in the US, which in policy circles is often discussed as following a more 'market'-oriented (liberal) model than Europe. This has not been the case where innovation is concerned.