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INNOVATION POLICY AND INDUSTRIAL STRATEGY FOR POST-COVID ECONOMIC RECOVERY

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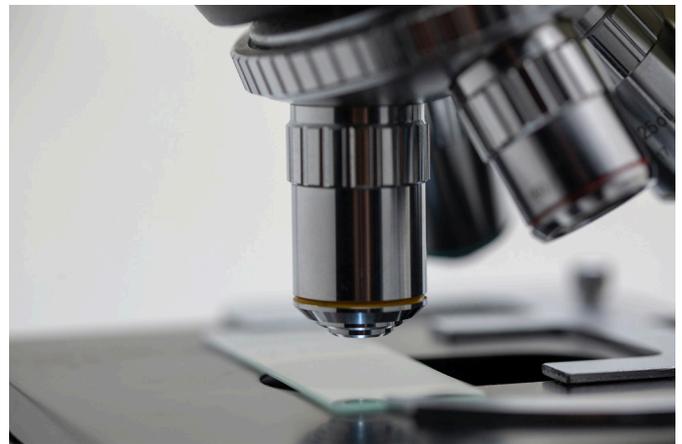
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The UK is facing three simultaneous crises: the immediate health and economic crisis of the COVID-19 pandemic; a longer-term crisis of low growth and productivity originating in the 2008/9 financial crash; and the global climate crisis putting our environment at risk and driving significant economic transitions. The inter-linked characteristics of these crises will define the 21st century and the UK government urgently needs the capacity and tools to confront them head on.

In this difficult context, challenge-oriented policy is key. At the UCL Institute for Innovation and Public Purpose (IIPP) we have been advocating a challenge-led approach to innovation and industrial policy. Innovation policy and industrial strategy offer opportunities for countries around the world to structure strategic investments and interventions to support innovation-led economic growth in the recovery from the economic crisis triggered by the COVID-19 pandemic. As part of this recovery, governments need to focus on both the rate and direction of innovation to ensure that our economic recovery is in a sustainable and equitable direction.



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Innovation is a key driver of long-term economic growth and is an outcome of collective value creation by businesses, governments and, increasingly, non-profit institutions. Investment in research and development (R&D) is a key input to innovation, from both business and government, and increasing the overall investment in countries is crucial to drive innovation-led growth. However, the structure of that investment is just as important as the quantity.

In many countries where business investment on R&D lags, it is crucial to consider how strategic public investment can crowd in private investment. This means, in some cases, relying less on indirect incentives and more on direct, mission-oriented investment that increases business expectations of future growth



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opportunities. In this context it is also then critical to ask what types of mission-oriented organisations are present. The characteristics of the Advanced Research Projects Agency (ARPA) model in the US can be used to also transform existing public investments, such as those in public banks. Furthermore, while most countries invest in R&D in higher education institutions, it is also crucial to ask how the entire innovation system can be made more interconnected and be supported, including for example the existence of public laboratories.

The R&D challenge

Internationally, there has been a return of industrial strategy and innovation policy, and a comprehensive focus on how economic growth can be delivered through innovation. This is all the more important now as countries attempt to stimulate economic recovery.

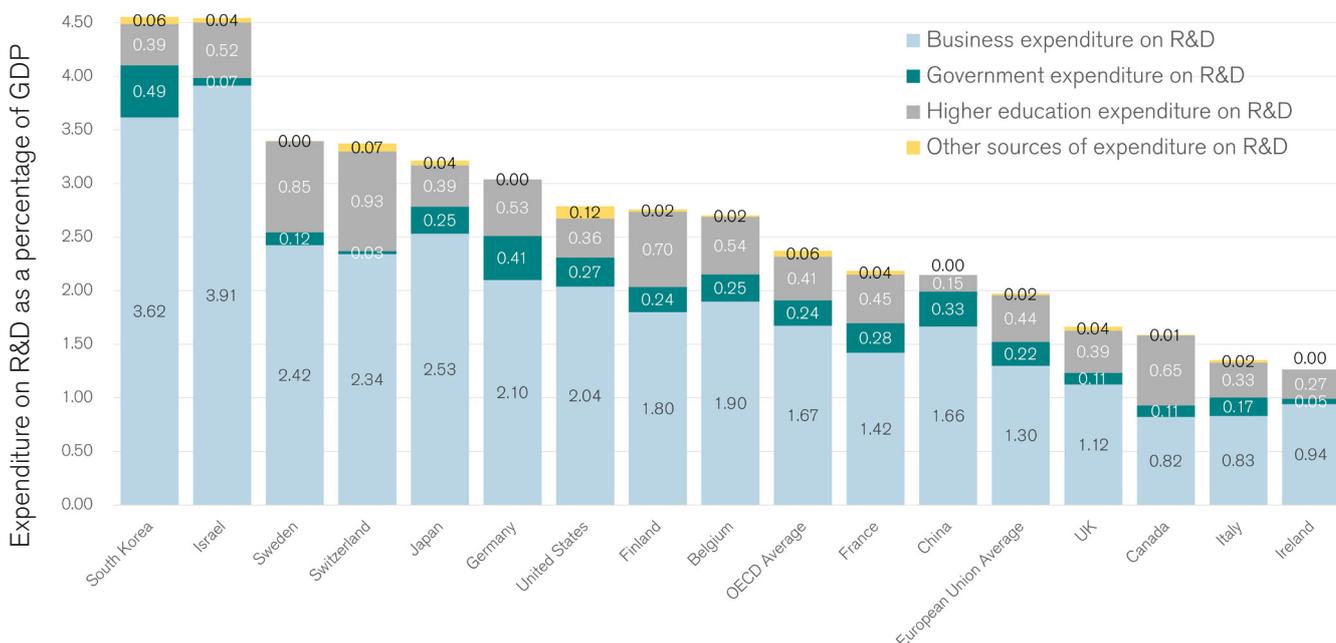
Levels of R&D investment within advanced economies vary significantly (Figure 1 and Figure 2) around the OECD average (2.4% in 2015), with the UK having lower rates of gross R&D spending (1.7% in 2016) compared to France (2.3%), USA (2.7%), Germany (2.9%), and Japan (3.1%), with the highest levels being in South Korea (4.2%). Many countries have ambitions or policies aimed at increasing gross R&D investment levels with the hope that this will result in increased productivity, technological innovation, and other economic benefits. For example, the UK has a policy to reach 2.4% of GDP by 2027 (Department for Business, Energy and Industrial Strategy,

2017) and Finland is aiming for 4% by 2030 (Research and Innovation Council of Finland, 2017).

The breakdown of R&D between the public and private sector also varies significantly between countries whether by investment or expenditure. A higher R&D spend should be matched by increased attention to the different components of the total expenditure on R&D across the economy. This gross expenditure is made up mainly of business expenditure, government expenditure, and higher education expenditure. The breakdown of expenditure between these sectors differ between countries (Figure 1). However, expenditure is distinct from investment — expenditure figures record who is spending funds, but not whether those funds originate from public or private investments. For example, a business funding R&D through a government innovation grant would show up as business expenditure, even though the investment is financially from the public budget. A nuanced consideration of these different aspects of R&D investment and how they are connected is important for any country aiming to increase their gross expenditure (Figure 2). Any roadmap for increasing total spending on R&D must include considerations of the structure of the system of innovation, ensuring an interconnected networked entrepreneurial state (Dibb 2018; Mazzucato and Lazonick 2010).

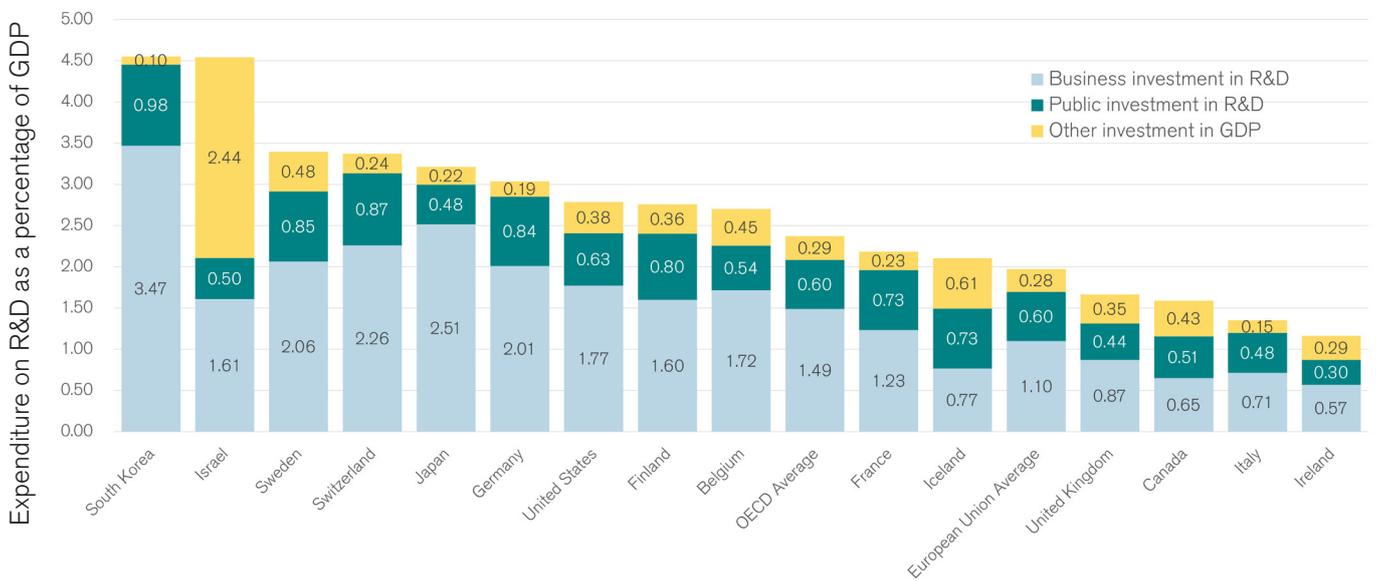
For example, in the UK evidence shows that public and private expenditure have been decreasing as a percentage of GDP since the 1990s, whilst the private

Figure 1: Expenditure on R&D as a proportion of GDP broken down by type



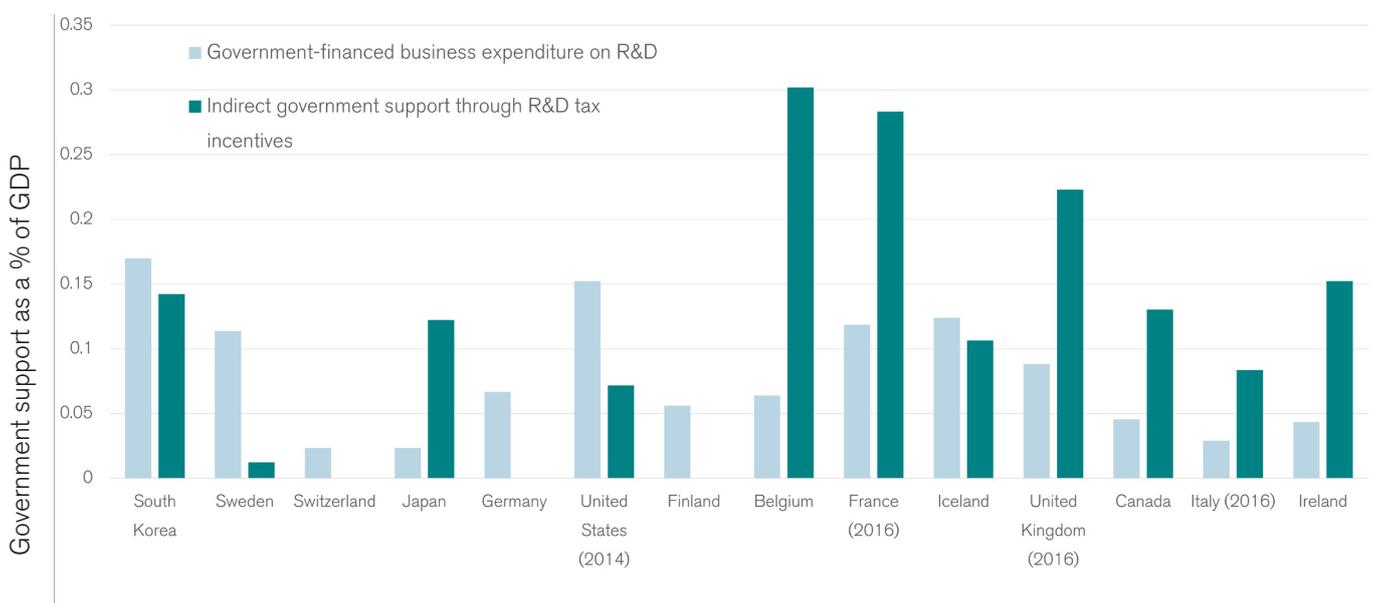
Source: OECD Science and Technology Indicators, 2017

Figure 2: Investment in R&D as a proportion of GDP broken down



Source: OECD Science and Technology Indicators, 2017

Figure 3: International comparison of direct and indirect support from governments for private-sector R&D as a proportion of GDP



Source: OECD Science and Technology Indicators, 2017

sector makes up a lower proportion of gross expenditure when compared on an international basis, even when corrected for structural differences (Hughes and Mina 2012). A recent report by the Government Chief Scientific Officer found that government expenditure on R&D in departments without protected budgets, such as defence or international development, have faced sustained reduction since 2005 (Government Office for Science 2019). 'Real terms' spending on R&D in higher education has also been falling whilst international competitors have been increasing theirs since the 2008 financial crisis (Tooze 2019; UCL response 2018). Overall, falling private-sector investment making up a low proportion of overall R&D expenditure is symptomatic of a lack of UK investment opportunities.

Furthermore, government 'direct' support for innovation via investments and grants is supplemented with 'indirect' expenditure through broad measures such as R&D tax incentives. Figure 3 shows that there is a large variation in how nations divide R&D support between direct and indirect measures. It is well documented, for instance in Canadian and Dutch studies (Dagenais et al 1997; Lokshin and Mohnen 2013), that such indirect measures of R&D financing often do not make things happen that would not have happened anyway, also known as additionality.

Crowding in or crowding out?

Critical to increasing total investment in innovation is the structure of the policies that will create a crowding-in effect: economy-wide investment.

Conventional macroeconomic frameworks frequently assume that public-sector investment crowds out investment by the private sector. An alternative view is that private investment is affected by factors such as levels of demand and effects of innovation processes on methods of production used by firms. Consequently, an increase in certain forms of public investment, properly structured, can engender a crowding in rather than a crowding-out effect.

Companies invest in R&D not because of short-term profit margins, but because of expectations about future profit and market opportunities (Mazzucato 2013, Mazzucato 2017, Deleidi et al. 2019). An ambitious industrial strategy structured around solving challenges and stimulating technology development can increase business expectations of growth in new areas therefore stimulating private-sector investment (MOIIS, 2019). Because these policies are systemic and focussed on the creation of structural transformations, they are more likely to crowd in the R&D spending of private firms by generating spin-offs through which research and innovation are developed and diffused to other sectors.

Ambitious public investments can catalyse and leverage private-sector investments through a mission-oriented industrial strategy. Missions, by their nature, are designed to provide direction for economic growth, helping to crowd in commercial investment by guiding business expectations around where future growth opportunities might lie. Missions need to be chosen to address clear challenges that stimulate the private sector to invest where it would not have otherwise invested — in business terms known as additionality. Directed and strategic investments by governments are not only catalytic (in that they crowd in private-sector funding alongside public) they also stimulate additionality i.e. they lead to investments that would not otherwise have occurred.

Missions will not normally be achieved by following a single development path, or by a single technology. They must be open to being addressed by different types of solutions. A mission-based approach is clear on the expected outcome. However, the trajectory to reach the outcome must be based on a bottom-up approach involving multiple potential solutions — of which some will fail or have to be adjusted along the way (Mazzucato 2018).

Investment and the public-private 'multiplier'

Increasing the levels of investment in R&D will require investment from both public and private sources. Critically, these increases in public spending should be structured to crowd in the maximum private-sector investment. Furthermore, public funds should be invested through a strategy which can maximise the public return to the taxpayer.

Some countries have successfully increased their R&D investment through strategic interventions. South Korea has the highest levels of R&D intensity in the world and have consistently increased gross R&D expenditure year-on-year with a bold industrial strategy since 1999. Since the founding of the South Korean strategy known as Vision 2025, between 2000 and 2016, levels of R&D expenditure have risen from 2.2% to 4.2% of GDP (Tooze 2019). In the UK, the government are have committed to increasing levels of R&D intensity in the economy from current levels of ~1.8% of GDP to the OECD average of 2.4%, but what levels of increases in public investment does this imply, and how can policies be structured so to crowd in business investment to raise the overall expenditure on R&D?

Calculation of these projections requires setting out the public investment, but also assumptions of the magnitude of private-sector investment which is harder to prescribe or predict. The relationship between public and business

investment in R&D — the so-called R&D multiplier — can be affected by many different factors. As discussed above, private-sector investment can be crowded out (a negative multiplier) or crowded in.

This raises a question of how to best structure government investment in R&D so as to result in the maximum additional private-sector investment, to maximise the so-called 'multiplier' of public spending. This can be done with a comprehensive innovation and industrial strategy that recognises that R&D is just one stage in a long innovation chain that spans from curiosity-driven research to commercialisation. Taking a systemic view of the innovation process can ensure that the public and private sectors are aligned. We propose specific policies to enable this later in this policy brief.

Analysis of the macroeconomic impact of different types of fiscal policy indicates that government spending directed at mission-oriented innovation has the potential to create a significantly larger economic multiplier due to its cross-sectoral effect, as well as the leveraging effect of crowding in private finance (Deleidi et al 2019). Research indicates that focussing on specific missions creates new markets and generates expectations of future growth in new areas, creating investment opportunities for the private sector.

Studies have indicated that for every £1 spent by the public sector crowds in, between £1.13 and £1.60 of private-sector investment (Economic Insight 2015). IPPR modelling of R&D spending forecasts in the UK assumes the more optimistic £1.60 multiplier figure (Parkes 2019).

Deleidi et al. take US military innovation spending as a proxy for mission-oriented innovation and compare that to 'normal' US R&D spending and broader government investment. In this paper, the authors use two different measures to measure the effect of public R&D spending on the economy; the first is the 'GDP multiplier' which shows the impact on the national economy of an increase in public spending and the second is a 'private-sector R&D' multiplier which measures how much private R&D spending public investment generates. The authors take US military R&D as a proxy for mission-oriented, outcomes-focussed, and directed innovation spending. Military R&D in the US was more focussed on early stage R&D process, with likely larger implications in terms of spillovers to other sectors and structural transformations of the economy than civil innovation spending. This analysis empirically indicates that the 'GDP multiplier' from mission-oriented innovation is about four times higher than standard investment spending. Furthermore, the 'private-sector R&D multiplier' for mission-oriented innovation is twice that of standard R&D spending, and six times higher than standard public investment.

Similarly, a recent study by Moretti et al. (2019) analysing both OECD nations and firm-level datasets found a significant crowding-in effect, rather than crowding-out, of public investment in defence R&D, both within the specific country where the investment occurs and internationally. The authors find a 10% increase in government-financed private-sector R&D generates 4.3% additional privately funded R&D. They also connect this to increases in productivity, economic growth, and R&D employment and wages.

Policies to support innovation-led economic recovery

Here we propose a package of government policies that can be adopted by any country or government seeking to reorient economic growth to be more innovation-led and to steer the recovery from the COVID-19 crisis towards societally desirable outcomes such as decarbonisation. The policies proposed below are supported by research on mission-oriented innovation and innovation systems at IIPP which indicates they can achieve innovation-led economic growth. These policies form a strategy of public investment in innovation to develop solutions to wider societal challenges and inequities, whilst also designed to crowd in private-sector investment. This would involve an uplift in public investment in science and technology to boost radical innovation, but also policies to address the systemic innovation challenges and to take a more networked view.

These policies were initially developed for a UK context and therefore recommend adopting policies already common in other countries. However, the policy set as a whole presents a common vision that could be applied internationally. National contexts vary, but the principles embodied in these proposals can be interpreted in diverse contexts, and offer a portfolio of interventions across a national system of innovation.

We recommend focussing on:

- A. Innovation-led economic growth
- B. National systems of innovation
- C. A mission-oriented approach to innovation
- D. Long-term patient finance (a national investment bank)
- E. Public organisations and institutions (the ARPA model)
- F. Public-sector capabilities
- G. Relationship between the public and private sectors

A. Innovation-led economic growth

Recommendation: Put innovation, science, and industrial transformation at the heart of a bold innovation-led economic growth strategy (to steer away from consumption-led growth)

Innovation is a key driver of long-term growth. Indeed, for much of the 20th century, economic growth (in the US and developed economies) has been fuelled by innovation, with businesses and public agencies together playing an important role.

But that is changing. Today we have public-sector institutions that are constantly asked to prove their 'economic value', forgetting that some of the greatest benefits to business from public R&D emerged when the goal of the investments was not commercialisation per se, but solving grander societal and technological challenges. Narrowing the purpose of the public sector to simply 'levelling the playing field' or 'de-risking' the private sector, ignores some of the greatest feats of the US innovation model, which were guided by mission-oriented investments, creating, and shaping markets not only 'fixing them'.

The 2017 UK Industrial Strategy presents an opportunity to harness our science, technology, arts, and industry to drive a new model of innovation-led economic growth. By looking across R&D, infrastructure, workforce, and

business environment policies the Industrial Strategy can both drive growth and prosperity and meet societal challenges. The Industrial Strategy must be supported in the long term, and this is the moment to reinforce it.

To do this, the approach and framework of strategic investments in science and innovation through the Industrial Strategy must be durable, forming a prominent part of the economic plan of this government. The Industrial Strategy must receive an ambitious uplift in funding to ensure its longevity and success. The radical technological and economic benefits of this approach must not be stymied by short-term economic thinking typified by cost-benefit analysis calculations.

B. National systems of innovation

Recommendation: Provide a radical increase in funding for a decentralised networked entrepreneurial state in science, innovation, and R&D, across the innovation ecosystem of universities, applied research centres, national laboratories, and others.

Mission-oriented innovation does not replace the need to build and enhance the strength of a country's technological and sectoral innovation ecosystem, but missions do depend on these systems. Achieving missions assumes that sectoral and technological capabilities are both in place. Without rocketry capabilities, the Apollo Moon programme would have not had much hope. Yet, it was that mission that developed that capability further and allowed it to interact with projects in other areas like computing, nutrition, and even clothing. Looking at the UK, the collaboration between universities, the High-Value Manufacturing Catapult and the Advanced Manufacturing Research Centre in Sheffield have led to the development of a high-tech supply chain cluster and attracted significant foreign direct investment from frontier firms such as Boeing. Attempts to replicate this success across other technologies or challenges should be pursued.

Industrial strategy is part of a national system of innovation that includes multiple types of organisations. The system itself is composed of sectoral and technological systems with specific configurations of private and public-sector firms, consumers, patterns of market and non-market interactions and regulatory and policy measures. These span basic research in universities and research institutes to more commercial companies.

This includes a range of intermediary organisations and public laboratories in between, exemplified by Catapult centres or Fraunhofer research centres. In the UK, the network of research capabilities, including those nurtured in public labs, has been thinned out over the decades (Dibb 2018). This infrastructure needs to be sustained and grown, and government should be patient supporters of these institutes and recognise that the application of research is valuable alongside new scientific discoveries.

Specific points on new public organisational structures and the foundation of ARPA-type organisations are addressed in Section E.

There is also a spectrum of funding for research that has direct public-sector support at both the basic and more applied ends. The latter include organisations that provide patient strategic finance (such as public banks), private-sector firms, public procurement such as the Small Business Research Initiative (SBRI) in the UK, and policy programmes to support collaborative R&D (including the UK Industrial Strategy Challenge Fund). Organisations and funding streams that provide connections and interactions between the more basic and applied ends of the research spectrum are a key part of sectoral and technological systems. Their existence, design and appropriate level of funding are essential components of a successful industrial strategy.

C. A mission-oriented approach to innovation

Recommendation: Maintain and strengthen a mission-oriented industrial strategy that provides a public-purpose framing for strategic intervention and fosters citizen participation in the innovation process.

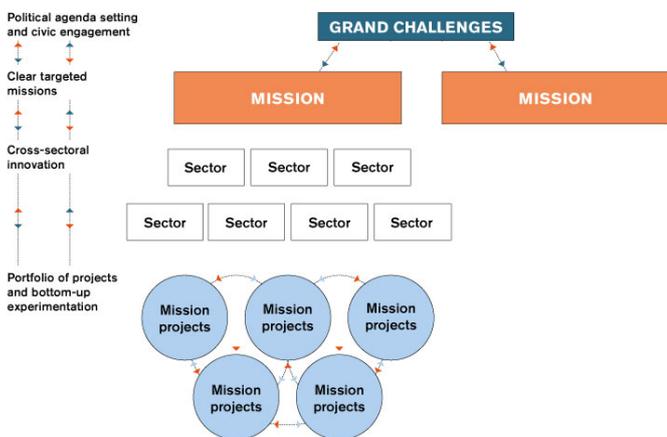
The ability of innovation to spur economic growth has long been recognised — but innovation has not only a rate but also a direction. By harnessing the directionality of innovation, we also harness the power of research and innovation to achieve wider social and policy aims as well as economic goals (Mazzucato 2018). This approach is needed more today than ever. The challenges presented by COVID-19 include the obvious healthcare needs that the pandemic has thrown our way—from PPE and ventilators to the race for a vaccine—but also the challenges that the rapid adaptation to a lockdown society has exposed: the digital divide between children trying to access school classes online, loneliness of the elderly, the privacy of our data in mobile apps, and the meta challenge of developing capacity across the public sphere.

Importantly, today's missions differ from NASA's original Apollo mission to the Moon because NASA's focus was on technological challenges. Today, with 'wicked' problems such as global warming, which require mass behavioural change alongside science and technology, the focus is on both technological and social challenges. This brings greater complexity to our solutions and means we must recast the policy measures needed to make missions work in the 21st century. Through well-defined missions to solve important challenges, policymakers can influence the direction of growth by making strategic investments and using suitable instruments across many different sectors. These create new industrial and innovation landscapes that build the confidence and growth expectations of the private sector that is crowded in. Here, governments act as market-shapers or market-creators rather than market-fixers.

Missions are sometimes confused with 'moonshots'. Moonshots make sense for purely technological areas, such as the Apollo program. With challenges that are more 'wicked' it is essential that moonshot thinking is linked with support to underlying government systems. For example, a moonshot around disease testing or health priorities must interact closely with the public health system, not replace or circumvent it. Missions are not siloed projects but are intersectoral, bottom-up, and build on existing systems (innovation systems and others) rather than sitting outside them.

To direct innovation towards challenges, they must be broken down into smaller, pragmatic steps. We term these missions, concrete targets within a challenge that act as frames and stimuli for innovation. Using missions to drive national industrial strategy or innovation policy means focussing less on sectors (the car industry or telecommunications) and more on problems that matter to all — problems that multiple sectors need to solve together. Missions can provide the means to focus our research, innovation, and investments on solving critical problems, while also spurring growth, jobs and resulting in positive spill-overs across many sectors. Missions also help define perceptions of future growth opportunities in ambitious ways, which in turn is known to drive private-sector investment.

Figure 6: From challenges to missions and projects



Industrial strategies have historically involved both 'horizontal' policies that try to improve conditions across the national economy — for example skills and infrastructure — and 'vertical' policies that target interventions in specific areas, notably sectors such as aerospace, automotive, or manufacturing. However, there is a compelling case for building a modern industrial strategy that addresses grand societal challenges by stimulating investment across, rather than through, sectors. The UK's *Industrial Strategy* published in 2017 confronted this issue and was structured around four grand challenges; clean growth, an AI and data economy, the future of mobility, and an ageing society.

In 2018, IIPP launched the UCL Commission for Mission-Oriented Innovation and Industrial Strategy (MOIIS) to help the government's challenge-led agenda be mission-oriented, with concrete goals that require multiple sectors to collaborate, invest and innovate. Chaired by Professor Mariana Mazzucato and Lord David Willetts MOIIS explored how policymakers could implement and deliver such a bold strategy and reported in May eight top-level recommendations and 25 implementation steps (MOIIS 2019). We believe that now is the time to reinforce this approach. The government should maintain and strengthen the existing mission-oriented industrial strategy that provides a public-purpose framing for strategic intervention and fosters citizen participation in the innovation process.

D. Long-term patient finance (a national investment bank)

Recommendation: Establish a national investment bank to provide patient and long-term finance for innovation.

Because innovation is highly uncertain and has long lead times, it requires a specific type of finance. Uncertainty means that finance must be willing to bear high risks; the long-run nature of innovation and its cumulateness imply that the kind of finance must be patient. Short-termism and risk-aversion means that the private sector has historically not invested in higher-risk areas until future returns become more certain. This is why across the world the early stages of the innovation chain are disproportionately occupied by public-sector actors, shaping new markets where the private sector can later invest and profit.

From advances such as the Internet and microchips to biotechnology and nanotechnology, many major technological breakthroughs — in both basic research and downstream commercialisation — were only made possible by direct public investment. In each of these areas the private sector only entered much later, commercialising the technological advances made possible by public funds. Given the high risk that such investments entail, new thinking is required to consider the appropriate risk-return relationship (Lazonick and Sakinc 2010; Laplane and Mazzucato 2019). The UK's response to COVID-19 has exemplified this with specific government support for high-risk start-up firms through the Treasury's Future Fund with convertible loans offering the potential for the government to take equity stakes in these firms.

Understanding how this was done — what works, what does not — requires learning from international experiences with financial institutions willing to provide strategic long-term finance. Simply increasing the availability of finance will not on its own improve economic performance. What matters is not just the quantity of available finance, but the quality of finance. This is because finance is not neutral; the type of finance available can affect both the investments made and the type of activity that occurs. The types of financial institutions and markets that exist have a material impact on activity in the real economy.

Patient finance has taken different institutional forms, but in many countries, this is increasingly coming from national investment banks (NIBs). The governance arrangements of NIBs typically do not create pressure to deliver short-term returns, meaning they can provide

financing over a longer time horizon, prioritise wider social and environmental objectives, and take a different approach to risk and reward. There is a growing consensus that NIBs that are challenge-led, with investment activities guided by specific missions aligned with government policy, tend to be more effective than those which are focussed on more neutral economic objectives such as promoting 'growth' or 'competitiveness'.

While the traditional functions of NIBs have been in infrastructure investment and counter-cyclical lending, in recent times they have taken on more active roles as key agents of industrial and innovation policy. In countries such as Germany and China, NIBs have taken centre stage in confronting the key social and environmental challenges of the 21st century, such as climate change (Macfarlane and Mazzucato 2018).

The UK is lacking in patient finance compared to other nations, and this will be exacerbated by Brexit as the UK loses access to the European Investment Bank. This is an opportunity to build new structures needed to bolster the UK's innovation-finance system (Mazzucato and Macfarlane 2017; Mazzucato and Macfarlane 2019).

An NIB can support investment in R&D by providing a range of tailored debt and equity-instruments designed to promote investment in R&D at favourable interest rates. An example of this is the European Investment Bank's 'InnovFin Emerging Innovators' and 'InnovFin Corporate Research Equity' products which provide tailored products

for or R&D-driven projects and enterprises.

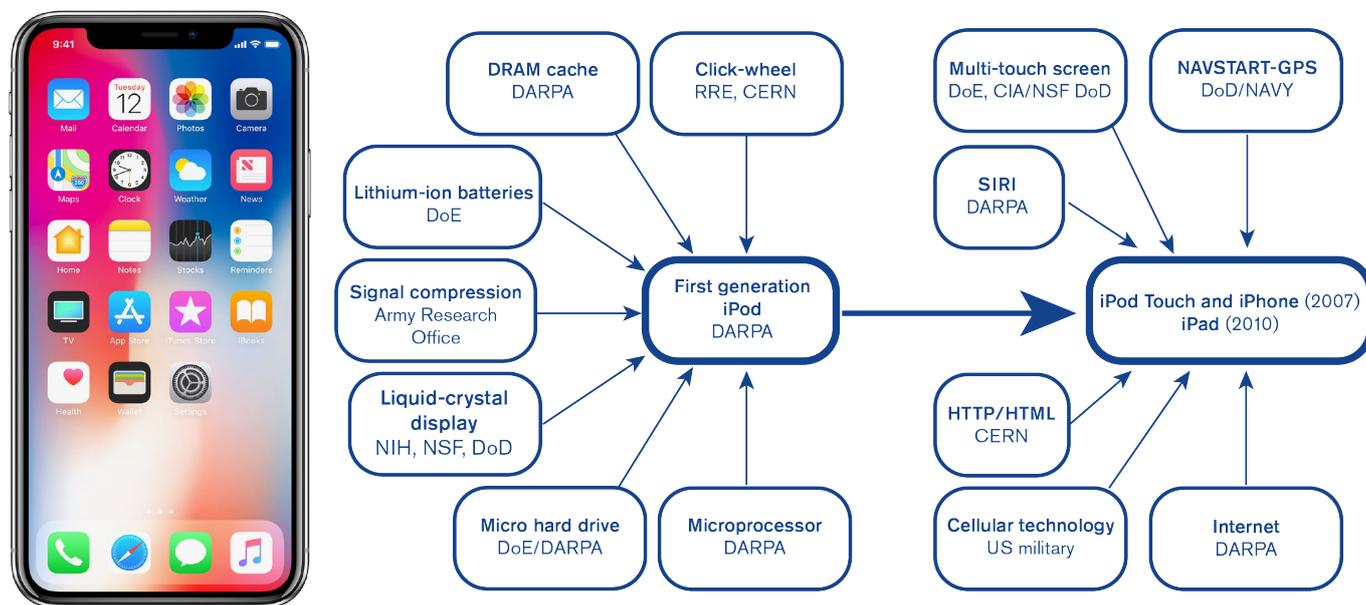
Many NIBs also play an active venture capital role, providing high-risk, patient capital for innovators and high-tech start-ups. Last year, Germany's KfW launched a new venture capital subsidiary aimed at improving the venture capital offering for innovative technology-oriented enterprises in the start-up and capital-intensive early growth phase. A new NIB could also create and manage a portfolio of public venture capital funds that would invest into innovative high-tech small and medium enterprises (SMEs) in their early and growth phases, targeting strategic sectors that have been identified by the UK Government's Industrial Strategy.

E. Public organisations and institutions (the ARPA model)

Recommendation: Establish an ARPA-style organisation with a challenge-led remit across the innovation ecosystem, connected into government procurement.

To drive innovation-led recovery we need the right institutions and organisations in place. In the US, ARPA invested in key areas across the entire innovation chain, not simply in curiosity-driven or blue-sky scientific

Figure 5: What could an iPhone do 'smartly' without the Internet, GPS, touchscreen display, and a SIRI voice activated system? —all financed heavily in the early stages through public funds, from a host of different types of public organisations



Source: Mazzucato 2013, p. 116

research, but in close-to-market innovation. Indeed, some of the greatest entrepreneurs, like Steve Jobs and Bill Gates, surfed intelligently on waves of publicly funded technology (Figure 5). Indeed, Silicon Valley would not have happened without a decentralised network of public actors across the entire innovation chain, from basic research, to applied research, to patient finance and dynamic procurement policies. To learn the lessons from this process, governments should review their current innovation ecosystem to ensure that they have the right institutions required on both the supply side and demand side.

IIPP advocate a challenge-led approach to innovation policy and industrial strategy — picking the problem, not specifying the technology or solution. It was defence challenges that gave purpose to ARPA, but that is not appropriate for the 21st century context.

- New ARPA-type organisations should be oriented around societal challenges with broad buy-in that define the 21st century and can just as effectively stimulate cross-disciplinary innovation, for example climate change.
- ARPA-type organisations should not be focussed only on new scientific discoveries but rather on transformational application, development, scaling and deployment of existing technologies.
- ARPA-type organisations should aim to leverage procurement and demand-side policies to 'pull' technologies and innovation.

The portfolio approach behind research and innovation exemplified by the 'ARPA model' requires the public sector to welcome the inherent uncertainty of innovation. Building public organisations in ways that allow them to welcome rather than to fear the trial-and-error explorative process behind innovation is challenging and a key part of the success of organisations like ARPA (Mazzucato and Penna 2015). Another key aspect of these agencies is how they have been able to attract talent and expertise by making it an honour for scientists to work towards solving grand challenges — this requires the role of civil servant to carry prestige.

The defining characteristics of the ARPA model are: (Azoulay et al. 2019).

1. Organisational flexibility
 - a. Independence from branches of government
 - b. Flat internal structure
 - c. Hiring outside standard government recruitment processes
 - d. Fixed-term employment of directors and project managers
 - e. Flexible contracting mechanisms
2. Bottom-up programme design
3. Discretion in project choice
4. Active project management

These characteristics should be replicated in any new ARPA-model organisation.

F. Public-sector capabilities

Recommendation: Reform current ways of working across government and develop public-sector capabilities to allow cross-government strategic working. This includes reform of policy evaluation techniques and reforming public procurement.

The policies proposed in this paper require the public sector to take a more active role as a shaper and creator of markets, and as an active participant and driver of economic activity. This is especially true in the case of mission-oriented innovation which requires the ambition to transform landscapes rather than just fixing problems in existing ones. To do so, public-sector organisations face a number of inherent barriers. Without addressing these in a systematic manner, the potential for success is limited. This is specifically addressed in *Governing Missions in the European Union* by Professor Mazzucato (2019). Here we address specific areas in which public-sector capabilities need increasing.

Flexible structures

As the response to the interconnected challenges of the COVID-19 pandemic from governments around the world has demonstrated, when faced with a challenge, it is possible to break down silos and work constructively across government.

Flexible and adaptive portfolio management can benefit from lessons provided by other innovation and funding agencies across the world, such as DARPA in the US, Yozma in Israel, Sitra in Finland, the Government Digital Service in the UK, or the Scottish National Investment Bank. The policy challenges of tomorrow will not necessarily accord with the departmental structure of the government today. For example, the grand challenges within the UK Industrial Strategy are bold messages that allow interdepartmental collaborations to happen — this must be valued and amplified. Breaking out of departmental silos will be essential in order to make the most of a country's talent for innovation and international competitiveness in building a better economy. MOIS proposed new cross-government teams to manage the grand challenges of the UK Industrial Strategy — this allows the teams to draw policy expertise from across government departments and technical know-how and expertise from a broad research and innovation infrastructure.

The portfolio approach needed to enable innovation-led growth requires the public sector to welcome the inherent uncertainty of innovation. Building public organisations in ways that allow them to welcome rather than to fear the trial-and-error explorative process behind innovation is challenging and a key part of the success of organisations like ARPA (Mazzucato and Penna 2015).

Policy evaluation and the *Green Book*

Mission-oriented policies or challenge-led organisations need to be evaluated as such and cannot be subject to static 'value-for-money' restrictions. All policies in the UK are appraised and evaluated using cost-benefit analysis set out in the HM Treasury *Green Book*. Strategic investment in science and innovation and a market-shaping policy approach requires a new analytical framework and tools beyond static metrics such as cost-benefit analysis and net present value. Such calculations would have stopped the Apollo Moon programme from ever getting off the ground. Because innovation in its very nature is dynamic and complex, new methods to model and capture their outputs and impact have to be formulated. Market-shaping, mission-oriented approaches encourage us to think big, endorsing ambitious policies to transform ways of working rather than fix problems in existing ones (Kattel et al. 2018).

The HM Treasury *Green Book* itself recognises that cost-benefit analysis (CBA) is not appropriate in all situations. It notes that:

'Social CBA and Social CEA (cost-effectiveness analysis) are "marginal analysis" techniques. They are most appropriate where the broader environment (e.g. the price of goods and services in the economy) can be assumed to be unchanged by the intervention.'

These techniques work less well where there are potential non-marginal effects or changes in underlying relationships.'

This limitation is of crucial importance.

To enable a successful industrial strategy that can leverage the kinds of policy instruments discussed elsewhere in this paper, a fundamental reappraisal of the role of public policy is required. This should go beyond the traditional market-failure framework to a market co-creating and market-shaping function. This new role would widen focus from marginal improvements in allocative efficiency driven by notions of 'value for money' to a broader notion of public value creation driven by public purpose. Such a framework needs to be able to capture spillover effects and structural changes to the economy that result from policy interventions.

Public procurement

Public procurement is a policy instrument that stimulates radically new technologies and can create new markets. The Internet, GPS technology, the semiconductor industry and passenger jets are the most prominent examples that resulted from government innovation-oriented procurement bringing along major economic and social impacts. However, often procurement ends up getting used to simply award the lowest cost bidder and often has to deal with contradicting policy goals such as cost savings, value-for-money, transparency, and siloed sectoral policy objectives such as environment, health, or employment. But this does not help to stimulate innovation or high-quality goods.

Therefore, public organisations should consciously develop capabilities for public procurement for innovation. A mission-oriented policy framework offers them a way to structure conflicting policy goals by specifying the end result (e.g. accident-free roads) based on criteria and characteristics, not the solution (e.g. driverless cars), and allow for plenty of space for experimentation. This helps to coordinate procurement processes across value chains and agencies. Effective public procurement for innovation and missions can create a 'pick the willing' dynamic rather than picking winners (Kattel and Lember 2010).

The European Commission has already taken steps to promote public procurement as a tool to stimulate innovation, by publishing guidelines on how to best do this. Public organisations can support innovations through procurement in several ways, which should all be considered as part of a mission-oriented policy framework. Public organisations can create new markets for products and systems that go beyond the state-of-the-art or they can create a demand 'pull' by expressing its needs to industry in functional or performance terms. Similarly, they can encourage innovation by providing a

'lead market' for new technologies/solutions or provide a testing ground for innovative products. The SBRI is a government funding stream that stimulates entrepreneurs to put forward innovative solutions for societal issues. SBRI falls under the category of pre-commercial procurement (PCP) and is used across Europe.

G. Relationship between the public and private sectors

Recommendation: Impose conditions upon investment in near-market innovation in the areas of transparency, reinvestment and knowledge sharing to ensure a public return on public investment and shape symbiotic partnerships between the public and private sectors.

Innovation systems in which risks and rewards are shared fairly among all actors are vital for fostering the dynamic and sustainable investments that are needed across the long and uncertain process of health innovation, and for producing a symbiotic, collaborative environment for health innovation to flourish. The existing paradigm of socialised risks and privatised returns needs to be replaced by one where public investment leads to public returns (UCL Institute for Innovation and Public Purpose 2018).

The state as an investor is like any other type of venture capitalist: it will sometimes succeed but also often fail. Precisely because it is investing in the areas of highest uncertainty that private capital fears, it will fail even more. But while private investors can use returns from the upside to cover losses on the downside, by not admitting the lead 'investor' role of the public sector, we have not allowed it to do the same.

The government must ensure symbiotic partnerships between the public and private sector. One way this can be done is by repositioning the way we structure public investments. Rather than simply setting the direction of the investment, policies could be bolder in setting conditions on how public benefit can be secured in key areas such as:

- Reinvestment: Ensuring profits of firms that benefit from public investment are reinvested back into innovation
- Knowledge sharing: Ensuring that the benefits of new knowledge flow within the system as well as out to the public at large

- Transparency of R&D costs: Ensuring informed discussion of pricing and R&D financing by clarifying real costs
- Conditions for access and affordability: Ensuring taxpayers do not pay twice for technologies developed with public funds (particularly relevant for medicines)

Considering the large amount of public financing that goes into R&D and the largest burden or risk bared by the state, governments have a responsibility to ensure that public money results in public benefit. The public should receive a return on public investments.

About MOIIS

IIPP hosts the UCL Commission for Mission-Oriented Innovation and Industrial Strategy (MOIIS) chaired by Professor Mariana Mazzucato and Lord David Willetts. IIPP has been breaking new ground with research on how government's through active industrial strategy can go beyond market-fixing behaviours and into market-shaping and -creating to drive economic growth and direct innovation towards solutions to grand challenges. The MOIIS Commission has been advising the UK Government on how an industrial strategy structured around such grand challenges can drive and direct economic growth and prosperity.

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