Research & Development Policy: An Overview of Key Thinking and Frameworks

30th September 2019

Prepared by:

Luke D. Bevan
l.bevan.17@ucl.ac.uk

UCL ENGINEERING
Change the world

STEaPP
Applied in Focus. Global in Reach.

Foreword

This report has been produced in as an accompaniment and background research piece to reports delivered to the UAE Office of Advanced Sciences.

It's purpose is to provide a broad background on the state of play in R&D policy, providing a open frame through which various policy ideas can be organised.

This report does not represent the opinion of UCL STEaPP or the UAE Office of Advanced Sciences. It merely reflects a broad spectrum of thinking from across academic and practitioner communities.

Citation

Please cite as:

Bevan, L. D. (2019). *Research & Development Policy: An Overview of Key Thinking and Frameworks*. London, UK: UCL Department of Science, Technology, Engineering & Public Policy (STEaPP).

Table of Contents

List of Figures

List of Tables

Executive Summary

This document provides a broad overview of contemporary thinking about R&D policy, with a particular focus on funding priorities and ideas about national innovation models. It contextualises many of the issues that policymakers face within the broader cycle of policymaking, considering the framings that surround agenda setting, the broad spectrum of policy instruments available, the key considerations that are made in selecting between these, challenges found in implementing R&D policy and how outcomes can be assessed for policy monitoring.

It begins with reviewing the key framings that shape thinking about what R&D policy should be and how these shape rationales. This considers and sets the roles of actors in the innovation system such as the state, private industry, academia and consumers as well as providing the justifications for policy action. Over the past century, three particular framings each come with their own rationales for policy action. These have been extremely important for the way that R&D Policy has been shaped and it is important to be cognisant of these of in the agenda-setting process.

1. 'The Endless Frontier': Government funding of science leads to an inevitable march of progress
2. 'National Innovation': Innovation is path dependent and is a core aspect of national competitiveness
3. 'The Great Challenge': Innovation involves a wide range of stakeholders and must help us face up to other contemporary policymaking challenges such as sustainable development

With this background, the various policy instruments available to policymakers for the promotion of R&D are mapped out and discussed in the context of these big ideas about what R&D policy *should be or do*. For example, a number of governments (such as the UK) have used market-based models to guide funding decisions. This stands in contrast to traditional ideas about academia being self-driving and curiosity driven. Instruments can be targeted at both the private and public sector:

In the public sector, the key instruments used to promote R&D are direct funding of either universities or research institutes. The typical mechanisms of funding has undergone a number of changes in the last couple of decades. Of particular importance is the influence of New Public Management (NPM) which has seen a shift to marketisation of university research and funding based on performance metrics. More recently, ideas about 'open innovation' and challenge-based research have permeated the policy debate.

In the private sector, R&D policy has focussed historically on a series of financial incentives, such as direct grants and tax incentives to encourage. This kind of government support is generally seen to be effective, up to a point at which there are diminishing returns from more generous programmes. However, less is known about the interactions of large portfolios of policies (policy mixes)- how to these polices act in combination?

A number of challenges for implementing R&D policy are identified, including pushing through the institutional reforms necessary and convincing a wide variety of stakeholders to have trust in the reforms being suggested.

Innovation and the products of research and development can be tracked in a number of ways, primarily but looking at input indicators (such as levels of R&D spend, number of researchers active), intermediate indicators (such as number of patents registered) and output indicators (such as numbers of new products brought to market). There has been a propensity in the past to focus on input indicators as an intuitive target. However, this may confuse means and ends as expenditure is not always necessarily effective in producing good quality research. Policymakers may wish to think about the outcomes they wish to see form the research system they are intervening in to decide the relevant indicators to track. This will also inform what sort of institutions are necessary for the management of that research system.

Putting all of these layers of the policy process together, an image of a national system can be developed. A number of countries seeking to emulate the research prowess of developed nations such as the USA, the UK and Germany have attempted to replicate some or all of their innovation policy. Such an approach is intuitive, but the experience of these countries urges caution for a number of reasons:

- Such approaches are not sympathetic to the contextual nature of research and innovation
- These approaches can lead to the abandonment of areas of indigenous speciality and overall strategic weakening
- Successful policy interventions consider the long-term development of local capabilities in locally sympathetic way

0 Introduction: What is R&D Policy?

This may seem a simple question, but as a matter of fact one that requires a little clarity. R&D policy overlaps with a number of other key areas of policy, including innovation policy so it is useful to see the relationships between them.

In accordance with Martin (2016), we define R&D policy as that which includes science policy and research policy, both for the public and private sector. 'Innovation policy' is normally said to be broader and also includes commercialisation policy. Overarching both of these is Science Technology and Innovation Policy (STI) policy. In this space of research there is relatively little consistency over terminology, and hence this report with focus on R&D policy yet acknowledges when ideas form overlapping domains are discussed.

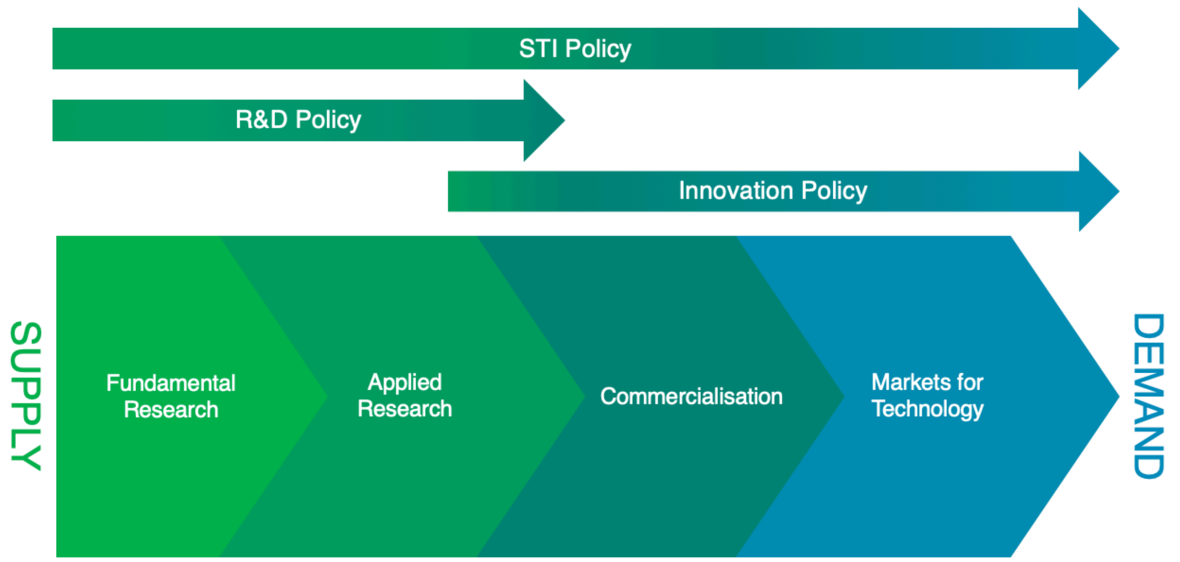

Figure 1: A simplified linear model of the roles of R&D policy, Innovation Policy and STI policy in the path from fundamental research to the marketplace for technologies

A substantial body of research exists which considers R&D policies from a purely economic perspective. Such research will often consider some narrow set of indicators relating to the performance of some policy programme. There is less research that considers from a policy perspective, looking at the overall impact policies and policy mixes have on a number of policymaking priorities (Sá and Litwin, 2011; Martin, 2016).

It is also informative to define a number of key terms. Taking after Popp (2010, p. 277), we define:
Invention: The creation of a new idea
Innovation: The development of new ideas into products, goods or services

Diffusion: The spreading of the use of the innovation

A full list of definitions, key terminology is available in the Glossary, towards the end of this document.

Doern and Stoney (2009, p. 16) provide an analytical framework for understanding R&D policy. They utilise four main components, which we will also roughly employ in our analysis and structure the following sections.

1. High Level Policy and Conceptual Discourse- what are the key narratives and framings used to understand R&D policy?
2. Policy Instruments- what are the policy instruments that can be used?
3. Core policy values and ideas – what are the key values and considerations that are in play when designing R&D policy?
4. Institutional and governance change- what does it take to implement these policies? What are the pragmatics of implementing R&D policy in the real world?

We have also aligned these considerations with where they are most relevant in the 'policy cycle'[1] to provide a framework for this analysis. Figure 2 shows how the various sections align with different parts of the policy cycle. In this way this document is intended to act as a guide to the process as a whole.

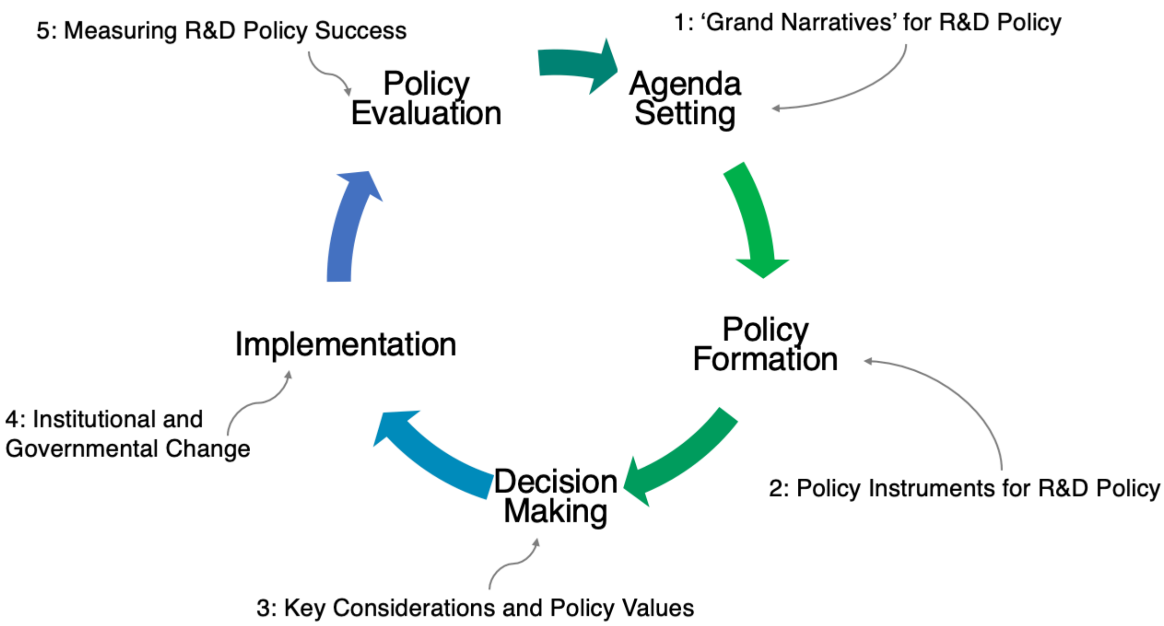

Figure 2: How the framing of this primer fits in within the policy cycle

[1] A tool used to understand the different phases of policy creation and implementation.

The **first section** describes a number of key framings that provide a rationale for policy action. We examine the key discourses that surround R&D policy in order explain how these shape rationales for policy action and policy preferences.

Section 2 describes the key policy instruments available for R&D policymaking. It examines some of the ways that they can be classified, in order to build a map of the policies available to policymakers. It then reviews a number of the key policy instruments, such as those concerned with R&D funding.

Section 3 examines how this multitude of policies can be sifted through: what are the criteria for selection between policies? What are the key considerations and trade-offs that need to be made?

Section 4 then considers how these policies are implemented. What institutional and governmental change comes alongside this? What practical considerations might there be in implementation?

Section 5 then looks at how these policies can be evaluated. What makes a policy successful and how can monitoring bets be put into practice? How can the success of R&D policy be measured?

Section 6 then looks at how these ideas operate in practice and how nations use models to structure their policy programmes. It asks if polices can be effectively transplanted between national contexts? What are some nascent lessons for those formulating policy and specifically for the UAE context?

1 Major Framings in R&D Policy

In this section we examine the high-level discourse, framings and 'grand narratives' that surround R&D policy, and STI policy as a whole. Put simply- what are the big stories and ideas about what R&D policy should be and when it is most effective at achieving goals? These high-level discourses influence the way that policy makers conceive of R&D policy and STI policy. They also provide what are known as *rationales*: the beliefs about the nature of the system that either implicitly or explicitly justify and shape policy interventions (Laranja, Uyarra and Flanagan, 2008, p. 823).

This section utilises the framework of Schot & Steinmeuller (2018), who enumerate three key frames that have shapes thinking about R&D and Innovation over the last century and in the present day. In describing each of these narratives, we will first furnish these with a short and approximate vignette of the framing, before detailing:

- The history of this frame- why do people think this way?
- The key considerations and roles of different actors within this frame – what is the role of government in this view?
- The policy implications of this frame- what types of policy intervention are favoured by this frame?
- Challenges to this frame- what are the drawbacks or issues identified?

It should be noted that the frames presented are somewhat of a simplification, and of course, very few sign up to the ideas contained within any one narrative fully. In fact, a number of different frames can be identified from actors in these systems (Khan *et al.*, 2016). These visions are important to understand as the collective visions of the future that people hold[2] shape their policy preferences and provide justification for government as a shepherd of the innovation process (Laranja, Uyarra and Flanagan, 2008, p. 824).

[2] These care called 'sociotechnical imaginaries' in the academic literature

1.1 'The Endless frontier of Innovation'

Science has always made substantive contributions to the development of industry. The ceaseless rolling back of the frontier of what we don't know by science has an enormous potential to promote growth and human flourishing. Negative consequences that emerge from innovation are largely the result of incomplete scientific knowledge, and when they do emerge are generally dealt with through more innovation. The role of the public sector is to generously fund science and the job of the scientists is to knuckle-down and produce transparent scientific reserach. The job of the private sector is to take these scientific discoveries and turn them into commercial innovations- fuel for long term economic growth.

Origins of the Narrative

This framing is highly influenced by post-war modernism and incorporates a great deal of optimism about the promise of technology to further society. After the industrial advances during the second world war, a consensus emerged that the state *can and should* support scientific research to contribute to the modernisation of industry (Schot and Steinmueller, 2018, p. 1554). A key metaphor to understand this is the idea of the 'endless frontier', popularised by Vannevar Bush[3] (1945) in a report[4] describing a vision for a post-war scientific research system for the United States. This is the idea that the role of science is to roll back the frontier of what we do not know. Through this ceaseless rolling back of the frontier, society benefits and there is an inevitable march of progress, with all of society benefiting from the fruits of knowledge.

Concurrent with the post war renegotiation of the role of the state, economists noticed that growth in productivity outstripped growth in capital and labour contributions. Hence it was discerned that technological advances were responsible for this productivity growth. These advances had their origins in scientific research- thus confirming the value of fundamental R&D to society (Schot and Steinmueller, 2018, p. 1556). Such an economic approach is broadly neoclassical and sees technology as an endogenous factor in growth (Laranja, Uyarra and Flanagan, 2008, p. 825).

[3] A celebrated American science administrator who was head of the U.S. Office of Science Research and Development (OSRD), during the second world war

[4] This report and later proposals by Bush lead to the creation of the National Science Foundation (NSF). Notably Bush's proposal beat out other proposals for the NSF which wanted the organisation to be administrated in a populist way, overseen by non-scientists such as consumers and business leaders (Kleinman, 1995)

View on the Innovation System

The model of innovation described by this narrative is simple and linear. Firstly, central government provides fiscal support to science, giving it autonomy over what and how it decides to conduct its research. Science then produces goods for society and business can capitalise on the result. In this model expanding consumption goes hand-in-hand with the technological expansion of civilisation.

The division of responsibilities in such a system is clear. The public sector provides a large supply side push by generously supporting scientific research. Scientists then conduct research, driven by curiosity or otherwise by a contribution to some loosely defined societal mission and with little mind for the eventual use of the knowledge. The private sector then capitalises on the products of the scientific advancement, turning the science into innovations and new products to bring to market. In particular it is perceived that large corporations have the capacity and the ability to perform this role (Schot and Steinmueller, 2018, p. 1557). Innovation also is imagined to happen without regard to context- the value produced is the same no matter where it occurs (Laranja, Uyarra and Flanagan, 2008, p. 826).

Any problems that may emerge as a result of technology are seen as soluble by further technological advancement or through some sort of regulatory agencies. These regulatory agencies perform risk assessments- which are seen as a sort of add-on to the scientific process (Schot and Steinmueller, 2018, p. 1556). Much of the regulation in this paradigm is ex-post[5] and issues that arise may be described as necessary costs of progress (Schot and Steinmueller, 2018, p. 1557)

The role of Policy in this view

Given that technological progress is said to be one of the key determinants of economic development, the question is then how best to promote the incentives of market actors to produce the desired level of scientific advancement? However, as the knowledge goods produced by research and development can be easily appropriated by competitors, it is considered difficult to incentivise firm-level R&D. In this way the private rate of return is lower than the social return[6] and the gap between these must be bridged (Hall and van Reenen, 1999, p. 1). Thus the production of these knowledge goods may be therefore subject to a market failure and government can intervene (Laranja, Uyarra and Flanagan, 2008, p. 825).

Another market failure includes the high risk hurdles that must be surmounted by firms engaging in basic R&D; research is an uncertain business and many firms will be put off by this uncertainty (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 226). In response to these issues, it is argued that public support should be provided to fundamental R&D to compensate for the misallocation of resources (Schot and Steinmueller, 2018, p. 1556). In

[5] Meaning “after the fact”
[6] An externality or market failure

this frame, latter stage research, such as the research necessary to bring a product to market, is not subject to the same risk of appropriation by market competitors (Schot and Steinmueller, 2018, p. 1556). Hence later stages of research are understood as requiring less government support to correct market failures.

Typical policy instruments in this frame that attempt to support R&D often involve fiscal incentives, such as tax credits or the creation of otherwise favourable conditions for firms engaging in R&D. With the supply-oriented model of innovation in which benefits flow to society inevitably from public investment, key indicators of R&D policy are research intensity as a percentage of GDP (Schot and Steinmueller, 2018, p. 1557).

There remain practical limits to the amount of money that can be spent on R&D as all government budgets are ultimately limited. Technology foresight exercises[7] allow governments to make strategic decisions, and these exercises may contain some consideration of societal factors, though they are often dominated by technological factors (Schot and Steinmueller, 2018, p. 1557).

Challenges to this view

One of the principle problems associated with this viewpoint is the limited understanding of the potential pathologies associated with scientific development. A reaction against a perceived form of mindless technological optimism was fomented in the 1960s, growing throughout the 80s spurred on by iconic science-related disasters such as Chernobyl. This in turn led to the creation of new regulatory agencies or the expansion of their powers; for example, the US FDA gained powers to regulate pharmaceuticals after the Thalidomide disaster (Schot and Steinmueller, 2018, p. 1556).

The linear model of innovation pays little attention to where the producers of knowledge are situated- it is as if innovation is occurring everywhere and nowhere in particular. Given that one of the primary determinants of technological advancement in this model is state funding, those richer governments able to provide greater support to fundamental research will see greater amounts of technological progress. This creates a distinction between the creators and the consumers of innovations, essentially the idea that there are winners and losers in the innovation game, particularly at a national scale (Schot and Steinmueller, 2018, p. 1557). Some national governments, particularly in east Asia, deployed more targeted versions of the policies advocated for by this narrative and observations of the success of these programmes lead in part to the emergence of the second narrative we review.

[7] Discussed in section 2.3.5

1.2 'The National Ecosystem'

Innovation happens in different ways in different contexts- it is also not always global and relies on having a skilled workforce and a supportive ecosystem of different organisations. Consequently, for nations to successfully harness the benefits of innovation and stay competitive with others, they must pay close attention to the way that innovation occurs in their country- innovation in Japan is not the same as innovation in France. Innovation also relies on the network of private and public actors- we need to facilitate link ups between academia and private industry to allow the easy commercialisation of the knowledge produced in research.

Origins of the Narrative

In the 1980s, there dawned a gradual realisation that spill-overs from innovation were not distributed evenly across the world: winners and losers were clear. Further to this, the disparity in outcomes was self-reinforcing: under a Schumpeterian economic analysis, these uneven advancements may lead to ever increasing returns on R&D investment thus a positive feedback loop causes a process of widening inequality in the outcomes of national R&D (Laranja, Uyarra and Flanagan, 2008, p. 826).

In response to the perceived issues with winners and losers, many national governments considered how not to be 'left behind' in the struggle for national technological competitivity. The differential success in the process of technological globalisation placed a new emphasis on the importance of fostering more effective local or national innovation policies and nit relying on the spill overs from other, wealthier nations (Schot and Steinmueller, 2018, p. 1558).

Furthermore, oil price shocks and the early-80s recession brought countries into greater strategic competition with each other. Concerns grew about the ability of richer countries to hoard the knowledge and benefits accrued through their more generously funded R&D programmes. Critical examination of the ideas associated with the 'endless frontier' framing lead to a number of observations (Schot and Steinmueller, 2018, p. 1558):

- Knowledge has a 'stickiness' and can be accrued by a nation, rather than flowing evenly throughout the world.
- Absorptive capacities[8] are important for understanding how firms can capitalise on innovations. R&D will be ineffective at driving growth if the skills necessary to incorporate it into business models are not there.

[8] "The ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities."(Cohen and Levinthal, 1990)

- These absorptive capacities are not only driven by education levels, but also by the value placed on entrepreneurship[9] by society.
- Innovation is path dependent. Disruptive innovations move the path of innovation and cumulative innovations reinforce it[10].

These observations about path dependence and the importance of local context were reinforced by the tremendous economic growth of east-Asian economies such as Japan, followed by the four "Tigers": Taiwan, South Korea, Singapore and Hong Kong (Schot and Steinmueller, 2018, p. 1558). The growth of these countries economically and technologically was seen to be the result of their strong local innovation systems, each appropriate to their particular national context.

Variations of this framing have proved very popular over recent decades and narratives around innovation systems are predominant in many countries (Sá and Litwin, 2011, p. 425).

View on the Innovation System

In this framing, the key to innovation is the cultivation of ecosystems of mutually supportive actors. This frame focusses less on the state providing support for early-stage or pre-commercial R&D, and more on the creation and maintenance of relationships between actors in the innovation system.

The previous frame did not consider the role of users or consumers of a technology. Here users have an inflated role and legitimacy and some basic level of consultation is considered appropriate.

Innovation is said to occur through the increasingly intertwined interactions of different actors. Thus, innovation can occur when academia interacts with business. The role of entrepreneurship is elevated in this view, concordant with the idea that absorptive capacity relies on the strong social capital of entrepreneurialism (Schot and Steinmueller, 2018, p. 1560).

The role of Policy in this view

Policy in this view has a focus around developing and maintaining networks of relationships between actors such as government, business and academia. However, there is a lack of consensus of what sorts of policies are most effective within this view. Hence a number of policy approaches have been made, including such policies as (Schot and Steinmueller, 2018, p. 1560):

[9] The social capital of entrepreneurship
[10] These two kind of innovation can be imagined as revolution versus evolution

- Policies that aim to align actors. An example is 'funding conditionality' in which funding for R&D is made conditional on cooperation with other actors.
- Support for New Technology Based Firms (NTBF) which are able to expand the based of R&D activities beyond what would be possible within the internal R&D systems of major firms.
- Attempts to stabilise demand for new products and services to promote technological diffusion. Though government procurement is generally less favoured
- Education of workforces that build absorptive capacity and human capital

The creation of networks might also be facilitated through policies such as the creation of science parks, which allow collaboration between industry and university researchers (Martin, 2016, p. 162). Other prominent strategies may involve the creation and promotion of spatially distinct innovative zones[11], though there is controversy as to whether these clusters can be reliably brought about deliberately as a result of targeted policy intervention or whether the process that leads to their successful creation is more organic (Laranja, Uyarra and Flanagan, 2008, p. 827)

Challenges to this view

One of the key challenges to this view is that these national systems of innovations fail to open the discussion about options to the wider group of people who are affected by innovation (Schot and Steinmueller, 2018, p. 1561). Funding for R&D and innovation is still seen, relatively uncritically, as a good in itself. Issues associated with this innovation can be considered by regulators, but the variety of options and pathways is not open for discussion.

Against this uncritical optimism, the next frame considers how a broader franchise of stakeholders, including marginalised groups, can be used to improve the innovation process and bring it into line with a number of other social or environmental goals.

In recent times similar framings have been manifested on regional and local levels with regional and local governments pursuing independent innovation strategies (Martin, 2016, p. 165).

[11] Areas where similar technology companies and researcher can be in close contact.

1.3 'The Great Challenge'

Innovation does not always necessarily mean social progress. We are faced with a wide variety of profound shared challenges, unconfined to national borders, from climate change to cybersecurity that demand our attention and require new ways of thinking. To unlock the potential for innovation to deal with these problems we must recognise that there is no one pathway to achieving a given goal and that the best strategy is to allow experimentation. We must open up the innovation process to a broader group of participants and collectively focus on solving large societal challenges. Identifying grand challenges can assist in the coordination of all of these actors and give social legitimacy to research & development.

Origins of the Narrative

Recognising the failure of national innovation systems to consider the role of a broader range of actors, and the shortcomings of the system in producing answers to the challenges of inequality, poverty and environmental collapse, a new frame emerged in the 2000s. It recognises that previous paradigms have been unable to manage the externalities associated with growth. The previous paradigms may exacerbate inequalities as they aim innovation towards the production of goods for consumers with higher purchasing power (Schot and Steinmueller, 2018, pp. 1561–2).

This new frame emphasises the importance of working towards grand societal challenges in areas such as energy, food, transport, water and healthcare, and is embodied in programmes such as the EU's horizon 2020 and the challenges laid out in the UN's Sustainable Development Goals (SDGs). Responding to these challenges require more than just doing more science and creating new technology products- it is also necessary to consider the path that society wants to take with innovation in a way that pays attention to the concurrent behaviour and social changes. For example, the development of the electric car is desirable, but needs to be twinned with a consideration of the changes of human behaviour that come with it and whether simply replacing all fossil-fuelled vehicles is the best aim of transforming the mobility sector (Schot and Steinmueller, 2018, p. 1562). In these so called 'socio-technical transitions'[12] there are interlinked and concurrent changes in aspect of society such as technology, skills, infrastructure, regulations, cultural predilections, among others.

This narrative challenges traditional views of technological advancement furthering society and the ability of government to ensure a reduction of inequality through a redistribution of

[12] The process in which new technologies are incorporated into society, and society re-adapts itself with the new technology

benefits of innovation. To deal with issues such as climate change, governments are able to invest in green technologies. However, for these investments to be successful there must be long term persistent or patient capital (Schot and Steinmueller, 2018, p. 1561). Is the state able to ensure a redistribution of the benefits of innovation, control tax avoidance and ensure this long term investment?

View on the Innovation System

In this model, the pathway to innovation is negotiated between a number of different actors- no one person is at the steering wheel of the innovation system. Actors experiment with different possibilities, recognising that there is no one route to the desired outcome. Through this process of experimentation, there may be an accumulation of knowledge and experience. This experimentation is said to be particularly productive in niches, which can then be upscaled to the whole system[13] (Schot and Steinmueller, 2018, p. 1563).

A key challenge in this model is how to manage incumbent networks and destabilise lock-in[14]. Incumbents may include existing industrial actors and elements of civil society (Schot and Steinmueller, 2018, p. 1563). This lock-in manifests itself in vested interests, pre-existing commitments and the cognitive challenges of accepting new paradigms.

In this framing, the goals of the sociotechnical transition are not met through redistribution of the surpluses of innovation, but through a co-creation[15]. Also the focus of innovation is global, as the problems that the transitions seek to solve are global (Schot and Steinmueller, 2018, p. 1564).

The role of Policy in this view

The role of policy in this view is to allow innovation as experimentation or as a search process on the system-level. The role of experience is values and the innovation process must be inclusive to gather as much value from diverse experience as possible.

Often the policy prescriptions involve the formation of some new public mission, though it is recommended that the missions are formed in some way that allows experimentation and different viewpoints (Schot and Steinmueller, 2018, p. 1564). Mechanisms must be developed to allow the participation of users in the system and for the creation of new demands and markets.

The process of anticipation is also important in this view. Deliberative processes may help identify the technological, social and environmental impacts of innovation (Schot and Steinmueller, 2018, p. 1564). However, these anticipatory processes cannot discover all

[13] Though the mechanism of up-scaling from niches is said to be under-explored by the literature
[14] Where incumbents are unable to escape from old modes of doing things
[15] Where different parties negotiate, formally or informally, a mutually desired outcome

potential outcomes, thus experimentation must be allowed to find the unexpected. Through putting experiments into practice, learning can occur, which can help reset incumbent mindsets. Thus, the three key processes that policy should facilitate in this view are:

- Anticipation
- Experimentation
- Learning

However, as this paradigm is still somewhat emergent, there do not exist a great deal of policy examples for study.

Criticisms of the first two frames included the idea that they are not properly attentive to the problems that arise as a result of innovation. This third frame notes the interlinked nature of different policy problems and linked STI policy to these issues in a more meaningful way. Thus R&D policy begins to overlap with more and more policy domains. This means that it may become more difficult to isolate the effect of a given policy instrument on the R&D or innovation system of a country.

Challenges to this view

There exist a number of challenges to this view:

- It may lead to stagnation as consultations slow down decision making
- It may provide excuses for a withdrawal of R&D funding
- It places additional requirements on marginalised actors in the system through participatory processes
- These processes themselves may be difficult to administrate and expensive
- Many of the ideas involved in this framing are new, and hence some policy instruments associated with this are less tried and tested

1.4 Comparison of the Frames

Table 1, overleaf, gives an Intercomparison of these three primary frames, considering the roles of different actors in the innovation system and summarising the general features of the conceptual models that guide thinking within these frames.

Narrative	The Role of…				Associated Economic Models	Models and Metaphors of Innovation	Governance Structures	Preferred Policy Instruments
	Public Sector	Private Sector	Science	Users				
1: The Endless Frontier	Generous funder of Science	Harnesser of scientific ideas for shared progress	Wellspring of new ideas and innovations	No Significant Role	Neo-classical Economics; (also Schumpeterian Growth Theory)	**Linear**: Government funds, science produces, private sector capitalises Funding>Innovation> Capitalisation> Growth	Research follows scientific curiosity. Standard model of governance, or revised-standard model.	Support for fundamental research.
2: The National Ecosystem	Coordinator of the ecosystem, moderate risk taker, creator of collaborative industrial community	Participant in national ecosystem. Entrepreneurs drive innovations.	Entrepreneurial science engaging with government and business and developing spin-offs from fundamental research	Limited, but noted role: To provide feedback and light input	Schumpeterian Growth Theory; Neo-Marshallian	**Interaction of actors** produces knowledge **Triple Helix:** of cooperation between academia, business and government Coordination> Strengthening> Competativity	Consultative	Aiding the alignment of actors' incentives; creation of ecosystems/ clusters like silicon valley, silicon roundabout (London) etc.;
3: The Great Challenge	Investing for the long term and regulating the ill-effects of modernity, Identifier of technology failure, risk taker	One player among many. Diverse forms of firms exist.	One player among many. Research and expert knowledge are produced in a societal context.	Significant role: consulted or invited into the innovation process	Systemic Institutional Approaches; Evolutionary	**Experimentation** drives disruption and change, overseen with healthy scepticism. A **search process** aiming for particular goals. Anticipation> Experimentation> Learning	Consultative or Co-constructive	Destabilisation of incumbents. Facilitation of communication between producers and consumers (e.g. knowledge brokerage).

Table 1: Comparison of three key framings for R&D Policy

1.5 Additional Influential Frames and Models

The three framings described in detail above are not all encompassing, though they provide grand overarching stories about what innovation or R&D is, situating the role of the state and other stakeholders within this, there are other frames and models which are prominent in discourse that are worthwhile paying at least a little attention to. This sub-section gives very brief unconnected vignettes for a number of other influential ideas about STI policy and innovation.

New Public Management

New Public Management (NPM) refers to a philosophy of government and a normative movement that seeks to restructure public sector organisations to make their operations more business-like (Eakin *et al.*, 2011). One particular exhortation of this view is that policymakers should ‘steer, not row’ (Peters, 2000, p. 40).

Rationales behind the movement include an improvement of managerial efficiency, a reduction of misaligned goals and an improved citizen access to services (Haque, no date). Increasing the productivity of public service provision through efficiency and value-for-money are key in the philosophy of NPM. Typical routes to achieving this efficiency include the marketisation of public services, competition for public contracts and the disaggregation of public services into their constituent components for cost optimisation (Robinson, 2015).

NPM-style reforms have been applied to research funding in a number of ways, in particular in the UK and the Netherlands, though NPM-style research policy reforms can also be seen in other countries that have not so vigorously adopted NPM in other areas of public life, such as Germany. Typical reforms may include (Ferlie, Musselin and Andresani, 2008, pp. 334–336):

- Market-based reforms such as competition for students and research funding
- Hardening of budget constraints
- Target setting as a means of control
- Performance Related Pay for researchers

Open Innovation

Pioneered in a book by Henry Chesbrough (2003), the concept of ‘Open Innovation’ is in opposition to mindsets about innovation and research that emphasise secrecy and the excludability of knowledge[16]. Advocates of open innovation want greater cooperation and transparency of research. It is noted that firms and researchers do not rely solely on their own research, but incorporates the ideas of others at every stage. By opening innovation and intellectual property, entrepreneurs can be afforded a wider menu of ideas that they can draw upon in innovative activities.

[16] So-called ‘closed innovation’

Evidence for the value of open innovation came from the low returns seen in 'fordist'[17] American companies due to unavoidable spillovers and the (Herstad, Bloch and Ebersberger, 2010, p. 114). Typical policies that aim to promote open innovation involve the promotion of networking or collaborations.

Many ideas around open innovation would sit comfortably in the second (somewhat) and third framings discussed earlier.

Responsible Research and Innovation

Responsible Research and Innovation (RRI) is a recent movement that attempts to reorganise the social contract between science, policy and society, acknowledging the inherent ethical and other values dimensions in scientific research (de Saille, 2015). Given that science and society are viewed as being inextricable, some argue that research agendas should be shaped by society. This responsible innovation must be reactive to concerns about the environment, ethics and other social sensitivities. RRI is found in operation in programmes such as the EU's Horizon 2020.

The Innovation Policy Dancefloor

An interesting metaphor for understanding the innovation policy process was developed by Kuhlmann et al. (2013). This systemic perspective casts the practice of science policy as an interaction between the actors involved in innovation practice (such as firms, researchers), public intervention strategies (policies), and innovation theory (the ideas guiding both). In the dancefloor that lies between these the challenges can be o create harmony of theory, practice and policy. The ways in which the three interact with and learn from each-other.

There are similarities with this idea and the idea of the "Triple Helix" of innovation. However the dancefloor metaphor stretches further: there can be changing music fashions that effect all actors- consider the three frames detailed in this section and how actors can be all aligned when each of these frames is dominant.

Table 2 provides a map of some of these systemic interactions

[17] Modes of company organisation that involve high levels of top-down organisation and in-housing of all activities

Table 2: Some typical interactions between different actors on the Innovation Dancefloor. Adapted from Table 1.2 in (Kuhlmann, Smits and Shapira, 2013)

	The Learner			
Learning from..		Practitioners	Policy	Theory
	Practitioners		Policymakers evaluate the impact of their interventions, they interact with businesses and gather opinions	Researchers conduct real world experiments and research on firms, Researchers gather experiences of actors
	Policy	Businesses adapt to policy measures		Researchers gather experiences of policy actors, research asses policy programmes
	Theory	Entrepreneurs adapt their mental models and adapt business models, Researchers act as consultants for entrepreneurs	Policymakers adapt mental models form theory, researchers act as consultants to policymakers	

The Entrepreneurial State

The concept of the *Entrepreneurial State* was developed by Economist Mariana Mazzucato and most famously popularised in a book of the same name (Mazzucato, 2013). The book examines how many key technological innovations of recent decades had underappreciated roots in government-associated research programmes and were not simply the result of private R&D. Examples of this include many of the key components of modern smartphones (GPS, touch screens, voice recognition). The moral of this story is that states have the ability to be risk takers and that innovation should not be left solely to private enterprise. The books has prompted significant levels of debate.

Experimental Policymaking in Science Policy

Policy experiments vary from constituting research, to an approach for the incremental implementation of policy programmes. They have seen particular popularity with the rise of behavioural economics, which often advocates real world testing of small interventions such as testing ‘nudges’ in Randomised Controlled Trials (RCTs). They also find broader applications outside of behavioural economic in a variety of domains. Other policy experiments may involve the restricted implementation of given policy to, say, a town and closely monitoring the results before rolling out the policy more widely. This experimentation phase provides an opportunity for learning.

Policy experiments may be popular with proponents of the third narrative previously examined, as it allows additional opportunities for creativity and learning.

2 Policy Instruments for R&D Policy

In order to understand the policy options available, it is necessary to provide somewhat of a map of the terrain. Martin (2016) notes that although the effectiveness of individual instruments has been often well researched, relatively little systematic evidence exists that compares the relative effectiveness of different instruments, side-by-side. However, this report will endeavour to consider the linkages with other large ideas about STI policy when discussing these instruments.

This section considers how the different kinds of policy instruments relevant to R&D can be disaggregates and what ideas they may be associated with. This is to give an overview of how a policy mix or portfolio of policies can be charted. It then looks at individual policy instruments and the research that has considered their benefits and drawbacks. This will also in greater detail into R&D funding policies and the considerations particular to them.

2.1 The Policy Cycle

Instrument exists at all stages of the so-called policy cycle[18] (Howlett, 2011). Though the primary focus on instrument selection occurs during policy formation.

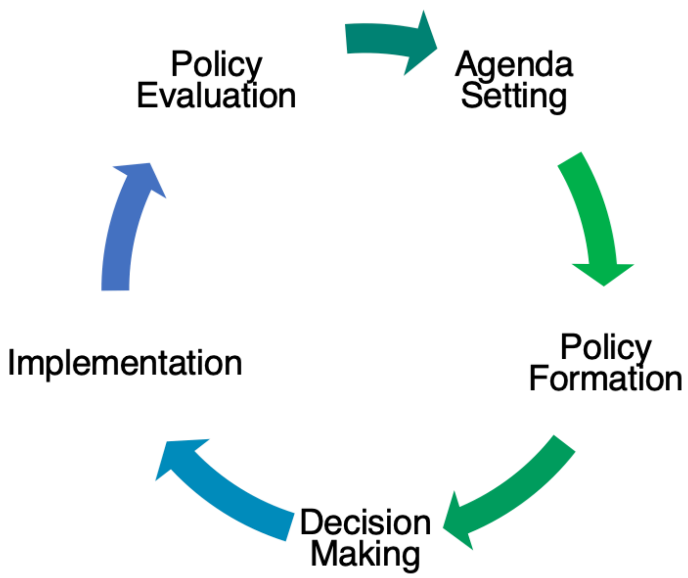

Figure 3: The policy cycle. Adapted from Howlett (2011)

[18] It should be noted that the policy cycle is a useful conceptual tool to frame the policymaking process, but nonetheless faces some limitations

During each of these phases different activities are undertaken (Howlett and Fraser, 2009, p. 26);

Agenda setting: Problem recognition
Policy formation: Proposal of solutions
Decision-making: Choosing a solution
Policy Implementation: Putting the solution into effect
Policy evaluation: Monitoring Results

2.2 Mapping out instruments

To understand the space of policies available for selection one can think of the map in a number of ways. This subsection provides a brief classification of tools to help frame the ensuing analysis and exploration.

A naïve and intuitive way of classifying the options available to a policymaker is to think of carrots (encouragements/ incentives) and stick (regulations and punishments). However this is very minimal and does not necessarily not give a feel for all of the range of options available in a context such as R&D policy (Martin, 2016, p. 160). One more extensive and popular system for understanding the range of policy instruments available is the 'NATO system', developed by Robert Hood, which classifies policy instruments according to the government resource expended in their operation.

Name	Nodality/ Information	Authority	Treasure	Organisation
Resource	Information collection and dissemination	Command and Control Regulation	Grants and Loans (Fiscal incentives)	Direct Provision of goods and services
Examples	Advice, advertising, promotional campaigns. Commissions and inquiries	Standard setting, self-regulation, consultations	Tax relief, incentive schemes	Use of community organisations, market creation, governmental reform

Figure 4: Adapted from (Howlett and Fraser, 2009, fig. 1)*, with own additions and modifications*

Howlett also provides another way of thinking about policy tools, according to what *style of governance* they require (Howlett, 2011, pp. 128–130):

Legalistic: A preference for direct government
Corporatist: Preference for state-owned enterprises and delegated regulation, the use of subsides
Market: Preference for deregulation and out-contracting
Network: Creation of interest groups, clientele agencies

Using these two frameworks we can classify the different R&D instrument options available to policymakers in a matrix, shown in Table 3, overleaf:

Table 3: Overview of R&D Policy Instruments, organised according to NATO and governance style. Inspired by Table 9.1 in (Howlett, 2011, p. 129)

		Style of Governance			
		Legal	Corporatist	Market	Network
Resources Deployed	Nodality (Info)	Patent protection laws	Government information campaigns	Production of R&D statistics/indicators	Promotion of research information sharing, Foresight Exercises
	Authority	Ethical Standards, Research Transparency and Accountability Rules			Stakeholder conferences
	Treasure		Subsidies for R&D, Research Grants, Funding of Science and TEchnology Institutes	Tax Incentives for R&D, Procurement Policies	Funding of inter firm R&D collaborations
	Organisation			Creation of Public private partnerships	Promotion of Scientific Mobility, Engagement with International Networks

Thus we can see that through an appreciate of the different styles a broad range of policies are in fact available beyond carrots and sticks. Policymakers have a broad menu of options for steering an R&D system.

2.3 Review of instruments

In this subsection we first consider the different ways in which funding can be allocated to academic research, before using the framework above to consider some of the other popular options. In particular we look at:

- Academic Funding R&D Policies
  - The role of different state-steering models
  - Performance Related Funding
- Financial Incentives for Private Industry
  - Direct Subsidies
  - Tax Credits
- Network Based Instruments
  - Policies to foment collaboration
  - Polices to Promote Clusters
- Foresight Exercises
- Public Engagement

There exists much research on the relationship between science and policy from an economic point of view, but less rigorous Intercomparison from a policy perspective. Much research focusses on the 'trinity' of policies: direct government funding of research (for government labs and HE), government funding of private R&D (through grants or procurement) and tax incentives for private R&D (Guellec and Van Pottelsberghe De La Potterie, 2003). We extend our review beyond finical instruments by considering a number of network-based instruments and the role of foresight exercises as a policy tool.

Each subsection of this overview begins with a simple statement of the mechanism of the policy, followed by additional commentary.

Figure 5, overleaf , is a dendrogram showing the many types of policies organised by target and style of intervention.

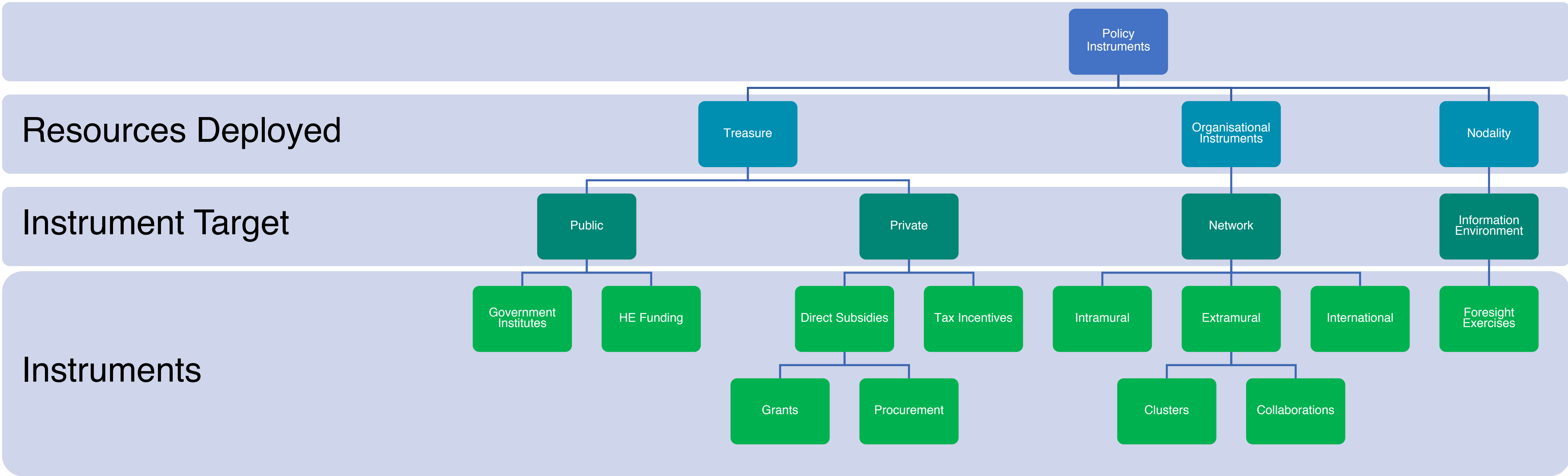

Figure 5: Map of different policy instruments relevant to R&D (and also partially Innovation Policy)

2.3.1 Government Laboratories

Governments may directly commission research to be carried out at public sector research institutes or centres

National labs are often a popular choice for the production. The logic for their creation is fairly simple as there is a direct line from a policy agenda to the commissioning and performance of thematic research. Prominent examples of national laboratories include CNRS (Centre National de la Recherche Scientifique) in France, NREL (National Renewable Energy Laboratory) in the USA and British Antarctic Survey (BAS) in the UK.

There may be issues with 'crowding out' of fundamental research. This is particularly true in some sectors such as defence, where public sector expenditure reduces private expenditure in the sector significantly (Guellec and Van Pottelsberghe De La Potterie, 2003).

2.3.2 HE Funding Allocation Policies

Governments give money to support research in Higher Education institutions, though the mechanism for providing this funding may vary significantly.

There exist a number of different fundamental approaches to the funding of academic research. Generally speaking, Universities have far greater autonomy in comparison to national research institutes (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 227). Higher education funding also does not have the crowding out effects of other capital intensive instruments (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 237).

Key aims of policy makers for HE funding include cost effectiveness of programmes and to achieve larger amounts of academic outputs, often measures in terms of publications or citations (see section 5) (Himanen *et al.*, 2009). Policymakers may use competition for resources as a policy level to steer universities and this is perceived as an effective instrument by many. However, the relationship between the state, markets, universities and other stakeholders is not universally regarded in the same way.

State-Steering Models

What are the different ways that governments can steer and how do these relate to ideas about styles of governance? It is important here to note that views on how HE funding is administrated come with them very articular ideas about what the relationship between the state and HE should be.

Himanen et al. (2009) use a framework for administration styles described by Olsen (1988) to analyse how different approaches to research funding administration may produce different results. These different administration styles are documented in the table below and can be seen to loosely align these with the governance framework from Table 3.

Table 4: Summary of different state steering models and how they come to play in HE funding policy

	Steering Style			
	Sovereign	Institutional	Supermarket	Corporate-pluralist
Similar Governance Style	Legal	Corporatist	Market	Network
Decision-making	Top-down	Delegated	Marketised	Distributed
Role of State	Director	Hands-off funder	Minimal	One of many stakeholders
View of HE	Tool of government	Uphold standards and cultural authority	Delivery of research and education services	Defined by constellation of interests
Assessment of functionality of Universities	Political Effectiveness	Maintenance of norms	Efficiency, value for money	Criteria set by multiple stakeholders

The **institutional steering model** may be related to Mertonian[19] idea that government should have a limited role in organising science, aside from ensuring its transparency and autonomy (Ferlie, Musselin and Andresani, 2008, p. 327). Such an idea corresponds well to the 'endless frontier' framing detailed in Section 1.1.

The **sovereign steering model** sees academic research as little different to other forms of public service delivery. Therefore academia is treated in a similar way to other parts of the public sector.

The **supermarket steering model** sees research outputs as a marketable commodity, rather than as a public good. This is very consistent with the NPM reforms of Higher Education in some countries, such as the United Kingdom.

The **corporate-pluralist model** may be possible to separate into different such as ideas about the devolution and decentralisation of decision-making in the 'hollowing out' of the nation-state or more democratic forms of higher education governance (Ferlie, Musselin and

[19] American sociologist Robert Merton (1942) set out some very influential ideas about what the ethos of modern science should be: communism (in the sense that scientists have common ownership of intellectual goods), universalism (the socio-political attributes of the scientist should have no bearing on knowledge), disinterestedness (acting in the common good, not personal gain) and organised scepticism (methodology and conduct should be subject to close scrutiny)

Andresani, 2008, pp. 332–334) (the latter may have resonance with the 'grand challenge' narrative frame section 1).

Himanen et al. (2009) tracked the role of these four models in influencing research outputs in five OECD countries and found that the relationship between the administration approach and research effectiveness was not always straight-forwards. In essence, the way that governments administer Higher Education or University R&D funding has a complicated relationship to the outcomes for that country's R&D system. Steering models have also been influenced by the rise of new public management (see section1.5), which pushes more towards the *supermarket steering model* and emphasises the use of performance related funding.

Funding Allocations and Performance Related Funding

Aside from administering programmes, decisions need to be made as to how allocation of funds necessary for research will exactly occur. Funding for research activities may come from government directly, or externally from sources such as private industry or other forms of revenue raising, such as charitable foundations. Direct funding from central government, which funds the things necessary for research to take place (such as staff, buildings, equipment etc.), may depend on different allocation criteria. Typically these criteria may describe the input to the university or the outputs of research.

The way these allocation criteria are organised will affect how competitive the system is (Himanen *et al.*, 2009, p. 421). There are also differences between what the UK government terms 'resource funding' for everyday running the research, and 'capital funding'[20] for new equipment, research centres and so on (Royal Society, 2018).

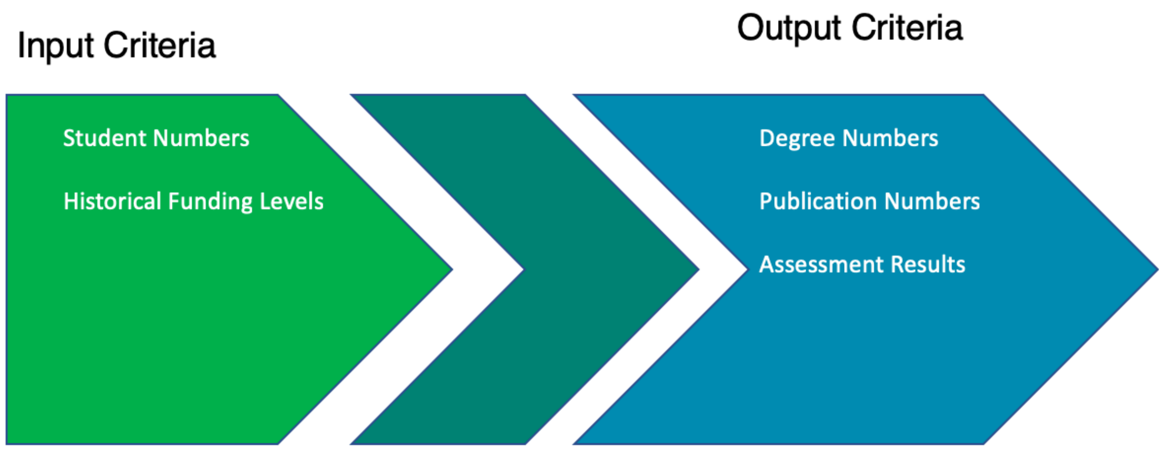

Figure 6: Examples of Input and Output criteria for funding allocation decisions

[20] These are essentially Operational and Capital Costs

De Boer et al. (2015) List a number of key indicators used by 13 polities in the allocation of funding.

Table 5: Summary of typical performance indicators adapter from de Boer et al (2015)

Indicator	Polity
COMMON INDICATORS	
Number of Bachelor/Masters Degrees	Austria, Finland, Netherlands, North Rhine Westphalia, Thuringia, Tennessee
Number of exams passed or credits earned by students	Austria, Denmark, Finland, Tennessee, Louisiana, South Carolina
Number of students from underrepresented groups	Australia, Ireland, Thuringia, Tennessee
Study Duration	Austria, Denmark, the Netherlands, Tennessee
Number of PhD graduates	Australia, Denmark, Finland, Thuringia, Netherlands
Research Productivity	Australia, Denmark, Finland, United Kingdom (England, Scotland)
Research performance in terms of winning (research council) contracts	Australia, Finland, Hong Kong, Ireland, Scotland, Tennessee
Third Party Income	Australia, Denmark, Finland, North-Rhine Westphalia, Thuringia, Hong Kong
Revenues from knowledge transfers	Australia, Austria, Scotland
LESS COMMON INDICATORS	
Internationalisation (student or staff)	Finland
Quality of education based on student surveys	Finland, Tennessee
Employability indicators, e.g. the number of employed graduates	Finland
Research quality	United Kingdom (England, Scotland).

It is generally considered that systems which focus funding dependent to a greater degree on output criteria and have greater shares of external funding are more competitive. Though it should be noted that competitivity does not necessarily entail effectiveness. Indeed some incentives may have very short lived effects or perhaps negative effects (Himanen *et al.*, 2009, p. 429). The law of unintended consequences is at work.

The final word in this subsection is to say that although funding allocation is a very large lever of policy, it is not the sole determinant of university research performance (Himanen *et al.*, 2009, p. 420). Research funding policy does not occur in a vacuum. It exists as part of a policy mix and this should be taken into mind when designing allocation policies.

Alternative Funding Models

A simple input-output model of funding is not the only basis for deciding how to allocate funding. It may be noted that not all research funding is utilitarian in nature and that research has a number of spill overs to other parts of life such as culture.

Performance related funding has a disadvantage that benefits are given after the fact, so that funding trails performance. An increasingly popular model is the use of Performance Agreements in which are signed between funding authorities and individual universities (Jongbloed *et al.*, 2018).

The Role of Research Councils

Governments may (partially) delegate funding decisions to research councils- often Quasi-Autonomous Non-Governmental Organisations (QUANGOs). This may be borne out of the acknowledgement that funding decisions should be placed in the hands of those better qualified than politicians to make the decisions.

Take the UK as an illustrative example, *United Kingdom Research and Innovation* (UKRI) is funded through the science budget of the Department of Business, Energy and Industrial Strategy (BEIS). This in turn is composed of seven thematic research councils, many of which have a long history in the UK. These research councils then autonomously assign funding through mechanisms such as peer review panels, grant panels, grant competitions and funding calls. Separate to UKRI, *Innovate UK* runs a variety of programmes to help in the commercialisation of R&D, through catapults and others.

2.3.3 Fiscal Incentives

Governments may also wish to incentivise R&D outside of an academic context by focusing on firm-level R&D. Firms may produce both basic and applied research. A perceived benefit to incentivising firm R&D is that firms are closer to the marketisation of innovations and therefore the beneficial economic impacts of R&D may be more immediate.

These measures are generally viewed to be effective at stimulating additional private sector R&D (additionality). However, this is only believed to be true up to a point- over generous incentives tend to lead to greatly diminishing returns. The two types of incentive considered here, tax incentives and direct subsidies, are also substitutes, meaning that they replace each other and may have diminish effects in combination (Guellec and Van Pottelsberghe De La Potterie, 2003).

Tax Incentives

A softening of tax burden on a company based on some measure of the R&D expenditure or intensity of a firm's R&D activities.

Tax credits have been a popular mechanism to encourage innovative behaviour in companies by different governments for a long time. As previously discussed, much of the rationale for this policy relies on ideas about the market undervaluing basic R&D (market failure rationale).

As these policies fall under the tax system, they often do not place additional burdens on ministries responsible for R&D promotion, but rather an overall burden on the tax system shared by the whole government. Further to this administration of the schemes is cheap as it falls under tax, so alterations of the scheme do not require great effort (Köhler, Larédo and Rammer, 2012). These tax incentives are also targetable towards particular forms of R&D that a government may wish to incentivise.

$$Cost\ of\ scheme\ =\ Decreased\ Tax\ revenues\ +\ Cost\ of\ Adminstration$$

Though cheap for the agency or ministry designing the scheme, these tax policies can be costly for governments overall. Though this can be limited with caps on potential tax benefits, and minimum R&D thresholds (Köhler, Larédo and Rammer, 2012). There are, of course, a number of different types of tax incentive that can be employed. They can be differentiates by their type of incentive and how the incentive is calculated (Köhler, Larédo and Rammer, 2012, sec. 2).

TYPE OF TAX INCENTIVE

Accelerated Depreciation:	Allow accelerated depreciation on assets used in R&D (this is an early form of scheme)
R&D Allowance:	Allow more than 100% deduction of R&D expenditure from income
Special Exemptions:	Allow deduction of particular costs, such as R&D labour
Tax Credits:	Allow deduction of R&D expenses from corporate tax liabilities
"Patent Box":	Tax relief on income from intellectual property generated by R&D (this is a new form of scheme)

CALUCLATION OF TAX INCENTIVE

Volume based:	Relief based on the volume (all of) of R&D in a fiscal year
Incremental Schemes:	Relief based on increases to R&D in a fiscal year

Further to this, policymakers must decide:

- How generous the scheme is to be? This is a primary determinant of cost
- What definitions are in operation? This includes the definition of who is eligible to receive the incentives (one may wish to target SMEs for example), what activities are eligible?
- The duration of the scheme
- Other scheme eligibility criteria, such as regional options

A report by NESTA, examining studies R&D schemes in 12 countries found that positive benefits are highly variable across national contexts (Köhler, Larédo and Rammer, 2012). They also note that:

- Volume based incentives and tax credits tend to be the most successful, but this must be balanced against their costs
- Incremental schemes are less effective under poor market conditions (such as during recessions)
- There is little evidence whether R&D tax incentives increase overall firm productivity

Direct Subsidies

Direct grants, either completive or non-competitive to firms engaged with R&D projects

Governments may simply decide to implement schemes that provide direct finding for R&D activities. There are of course different ways through which grants can be given out. These may be given out either on a competitive basis, or on a qualification basis. Under a competitive basis, firms must organise bids to secure the funding. On a qualification basis, all firms that satisfy some criteria may be eligible to receive the funds.

Similarly to research into tax incentives, much research in this space focusses on crowd-out effects and whether additionality (Görg and Strobl, 2007 See for example). Also, research that has attempted to understand the effect of grants has uncovered somewhat of a ‘chicken and egg’ situation (Wallsten, 2000). Is the correlation between R&D intensity and the reception of research grants due to the additional funding may increasing research activities, or is it that research intensive firms are more successful at obtaining grants?

These direct grants have the benefit of being very tailored and can be very highly targeted towards sectors considered worthy of support.

- The formation of research alliances (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 227)
- Minimum standards for research transparency

A key purported disadvantage is that is suggested that in providing grants, governments may be less efficient at allocating resources than markets (Guellec and Van Pottelsberghe De La

Potterie, 2003, p. 226). Thus, there may be an effectiveness issue. Also, as will be discussed in section 6.2, there is a tendency of a number of governments to provide targeted to support to technological research streams to which their innovation systems are not suitable to support[21].

Procurement

The government can use its purchasing power to support particular innovations, firms, sectors or products

Public Technology procurement (PTP) involves the government supporting particular technologies, or firms conducting R&D, through the procurement of their goods. Government procurement of goods and services more generally makes a very significant proportion of many economies (16% of GDP in EU15) so the potential of this policy lever is very significant (Nyiri *et al.*, 2007) Not all PTP is intended to support R&D or innovation per se, as it can be used to simply support domestic industry. Also PTP that is directed towards R&D may either support existing technologies, or provide a stable economic environment that allows domestic firms to justify the R&D necessary to create the procured products.

PTP requires the coordination of departments responsible for supporting R&D/Innovation and those responsible for procurement. Forming such collaborations can be non-trivial. It faces a number of barriers, such as low political risk appetite (Nyiri *et al.*, 2007).

Different nations, for example the United States and Japan have made more effective use of PTP as a policy lever in comparison to many European nations. Also, in some sectors, many nations have failed to support niches and have instead supported simple improvements to existing technologies (Nyiri *et al.*, 2007).

The recipient of the funding in this case need not necessarily be the producer of the research that lead to the creation of the product (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 227). This can create complex and skewed market environments.

2.3.4 Network-based Policies

Policies that aim to increase the amount of may be understood to:

- Increases knowledge share Intramurally (bringing collaboration and expertise into firms)
- Nationally or Regionally, through the creation of collaborations or research-intensive localities (see for instance the trend for "silicon-{valley, motorway, oasis, roundabout})

[21] Ideas about 'smart specialisation' have attempted to ameliorate this issue

- Internationally, through collaborations with international firms or research institutions

Collaborations

The government can use its organising and funding power to create collaboration between public and private sector actors.

When considering the potential for commercialisation, the funders need to be cognisant of the potential for exaggeration in commercialisation or spill overs as there can be disconnects between universities and entrepreneurs (Martin, 2016, p. 162).

Policies can aim to facilitate university and business research linkages (such as in the model of the triple helix) (Martin, 2016, p. 162). Further to this there are a growing range of policy tools that are focussed on promoting the commercialisation of policy tools. Though a drawback of this is said to be the focussing of research efforts on short term gains, rather than long-term outcomes.

Some policies may aim to facilitate inter-firm R&D collaboration. Some research has suggested that R&D subsidies are more effective for firms that collaborate internationally, as well as SMEs (Hottenrott and Lopes-Bento, 2012).

Clusters

The government can facilitate the creation of special districts with a beneficial business environment and similar firms or related research institutions in close proximity

Popular in recent discourse around innovation is the idea of clustering. Inspired by the success of Silicon Valley or Northern Italian industrial districts, policymakers have become sensitive to the idea of creating clusters to promote innovation and R&D. However, there may exist a gap between the vogueishness of the concept and the understanding of how to best promote clusters (Uyarra and Ramlogan, 2016). Terms that describe these geographic areas are *science parks*, *new industrial spaces, regional innovation systems and industrial districts* (Martin, 2016, p. 162; Uyarra and Ramlogan, 2016). These clusters generally entail specialisation, rather than simply being high-technology.

Clusters may emerge in a variety of ways and recognition of specialist clusters have existed for a long time. Generally, clusters may have some historical antecedents, such as the existence of some other industry in the area beforehand leaving a skilled workforce behind or the existence of a military base, for example. However, there is controversy over the extent to which policymakers can reliably found sustainable clusters or whthether these clusters are more organic in their origin. Here we see the importance of pre-existing human capital as a precondition for the creation of strong specialisation.

Actions to promote clusters may include (Rosenfeld, 2002):

- Identification of clusters, and the mapping of systemic relationships can provide a roadmap for supporting them
- The formalisation of communications channels within and to the cluster
- Providing state services to support the cluster
- Development of specialist workforces and human capital necessary to support cluster
    - The use of the cluster as place of learning
- The encouragement of local entrepreneurs
- marketing and branding a region to encourage inward investment
    - Also promotes exports
- Provide fiscal incentives for collaborations within a cluster

2.3.5 Foresight Exercises

The government can commission foresight exercises to anticipate future technological needs and to identify key challenges in the future. This informs smart policy development and can contribute to the coordination of a number of actors within the innovation system.

Foresight exercise can help in the formulation of policy strategy, identifying nation-specific opportunities and anticipate future technology demands. Through such exercises, governments can also attempt to manage the risk from innovation and research. Foresight can provide scenarios, forecasts and roadmaps (Meissner and Rudnik, 2017, p. 457).

The value in foresight exercises for STI policy is not limited to the increase in policy analysis capacity that they bring- they also provide opportunities for stakeholder engagement and the coordination of a number.

There are a wide number of forms that these foresight exercises might take and may be informed by activities such as modelling, technological assessment and public consultations. Recent approaches have begun looking at more 'integrated' approached to technology assessment, including a greater deal of information on societal considerations (Meissner and Rudnik, 2017, p. 457)

2.3.6 Public Engagement

Public Engagement can be a useful tool to shape innovation systems and ensure that R&D and innovation activities are in line with broader social ideals

Consistent with ideas about *responsible innovation*, governments can commit to public engagement and consultation to ensure that R&D and innovation is aligned with societal goals. Consultations can take a number of forms, from tokenistic engagement to full consultations where a broad variety of stakeholders are brought into the decision-making process.

2.4 Policy Mixes in R&D Policy

There exists relatively little research on how R&D policies can be mixed and the choices faced in R&D policy selection (Martin, 2016, p. 164). R&D policies may interact in often unexpected ways (Martin, 2016, p. 167)

One of the key trends in policy choices and mixes m sophistication of policy instruments is said to have increased over time[22] and the areas which these R&D policies cover has increased[23]. Broadening has been seen as R&D and Innovation policy has come to overlap with more and more domains of policy in recent years. In particular, policymakers have looked to innovation policy to aide in achieving a number of other societal goals[24].

When considering policy mixes, one may also wish to consider the various interactions between policies. For example, the two types of incentive considered here, tax incentives and direct subsidies, are also substitutes, meaning that they replace each other and may have diminish effects in combination (Guellec and Van Pottelsberghe De La Potterie, 2003).

Perhaps part of the difficulty in producing systematic analyses of instruments, is the fact that instruments never exist on their own, but always in a mix. Their efficiency is best captured through an examination of the system as a whole, though this is clouded by the sticky issue of how to determine if a policy has been successful (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 228).

The effectiveness of all of the instruments is not only affected by their design but also the level of funding available[25] and the stability of the policy environment- integrating instruments into a larger long-term framework reduces uncertainty. Further policy

[22] Known as *deepening*
[23] Known as *widening*
[24] Such an approach could be seen as being at least partially consistent with the 'the great challenge' narrative earlier
[25] Too little will have no effect. Too much will crowd out. This forms an 'inverted U' shape

instruments need be consistent, which requires the coordination and cooperation of a number of administrative departments involves in their functioning (Guellec and Van Pottelsberghe De La Potterie, 2003, p. 238).

Table 6: Overview of different policy instruments relevant to R&D

Instrument		Targeted at…	Instrument Resources and Associated Governance Style?		Purported Benefits	Purported Disbenefits	Typical Indicators for Monitoring
Public Research	Government Research Institutes	Public Sector	Treasure (Carrot)	Corporatist	• Targeted research on policy-relevant themes	• Crowding out of Private R&D • Does not increase private R&D expenditure (though this is not considered the purpose of this instrument)	Citations, Publications,
	HE Funding	Public Sector		Various	• Low or no crowd-out of private R&D • Universities are tried and tested institutions •	• Does not increase private R&D expenditure (though this is not considered the purpose of this instrument) • Knowledge produced may not be immediately commercially relevant	Citations, Publications, Doctorate produced
Direct Subsidies	Grants	Firms		Various	• Allows governments to 'pick winners' • Large number of potential criteria for eligibility can steer R&D • Particular national sectors and goals can be targeted	• Market forces may allocate resources for R&D more efficiently than government • Firms who are not recipient of government funding may be deterred to begin similar research projects • "Picking winners" is not universally liked	
	Government Procurement	Firms		Various		• Can create distorted market environments • Requires collaboration of both R&D, Innovation and procurement parts of government	

Tax Incentives		Firms		Market	• Simple administration through existing tax system. • Cheap for ministry organising scheme (as burden is on overall government revenues). • Wide range of design features allow policy targeting to particular forms of R&D • Easier to access for SME or new innovative businesses when compared of grants • May strengthen absorptive capacity of recipient firms	• Can be expensive overall for government with reduced tax revenues • "Crowding out effects" of private R&D • Benefits are received after R&D is performed so have less of an effect on overall strategy • The money received/saved by the firm will not necessarily be spent on anything with a large social rate of return • Tax break not necessarily accessible to companies with low tax burden, such as new firms with large investment and low sales. • Project that should be promoted are ones with largest gap between social and private return. Tax system does not allow this focus	Input additionality: Change in R&D expenditure as a result of incentive. (measured through natural experiments); Response Elasticity
Network Policies	Collaborations	Firms and Regions	Organisati on	Market/ Network	• Collaborations can increase the	•	
	Clusters				• Clusters can improve marketability of products they produce and stimulate inward investment	• There is controversy over the extent to which governments can authentically create new clusters, or if the growth process must be more organic	
	Foresight Exercises	System-wide / Policy Formation	Nodality (Informatio	Network	• Can promote the alignment of a number of different actors	• Foresight exercises may be limited when they consider only a small number of narrow factors, such as purely technological variables	

3 Key Policy Considerations and Policy Values

What are the key criteria and decisions that are made when selecting a policy? In this section we consider how the criteria for selection of a policy may be typically thought about. We then consider a number of trade-offs and dilemmas that typically arise in the formation of R&D policy.

3.1 General Policy Selection Criteria

Peters (2000) provides seven trade-offs or criteria for policy instrument selection. We consider each of these trade-offs in the context of R&D policy. Many of these choices will define the style of governance being enacted from more hierarchical, legal, or corporatist to markets or network-based measures.

Directness Vs Indirectness

This is a measure of how directly the policy is trying to influence the policy situation

Visibility

Visible tools can be more effective in setting the tone for a policy area, whereas less visible tools can manifest less political opposition.

Capital Vs Labour Intensity

A trade-off between spending on capital projects or labour-intensive activities. Labour intensive activities may require more managerial styles of governance to control personnel, whereas capital intensive [projects may require more ex-post evaluation.

Automaticity/ Level of administration Required

Will the programme ‘run on its own” or will it require updating?

Level of Universality

Is the programme applicable to all stakeholders?

Information Vs Coercion

How reliant is the programme on Persuasion vs Enforcement?

Forcing Vs. Enabling Nature

Does the programme compel stakeholders to behave in a certain way, or make it easier for them to behave in a certain way?

Potential policies can be evaluated on criteria such as these to help determine their suitability for a government's particular context.

3.2 STI-Specific Policy Considerations

Here are a number of additional considerations that are particularly relevant to the domain of STI policy.

3.2.1 Linear and Systemic Thinking

As previous discussed in section 1.4, the transition between the frames in recent years has coincided with differing policy concerns. One of the most pronounced is a move from thinking about innovation systems in a linear way (i.e. government funds, science produces and society benefits) to a systemic way that either considers the innovation ecosystem or how a broad range of stakeholder participate in innovation (Martin, 2016, p. 162).

The question for policymakers is then: how to ensure that R&D policy instruments are sufficiently target at the systemic changes they seek to encourage?

3.2.2 Area of Governance

In section 2.4 we discussed how policy portfolios have broadened to include a larger range of policies. Policy portfolios for R&D policy also increasingly overlap with other policy areas as policymakers hope that innovation can ameliorate other societal issues. This has always been true in defence, but it extends to other areas. Take *climate change* for example: there exists significant governmental in many polities funding for green innovations such as new renewable energy technologies; thus energy and environment policy links up with innovation policy. This bleed of R&D policy into other is particularly relevant when considering the 'grand challenges' policies (Martin, 2016, p. 166).

The question for policymakers is then: which other policy priorities are to have a bearing on R&D policy?

3.2.3 The Level of Governance

In the early days of R&D policy, the most significant actors were national governments. This is not the case anymore as regional governments and a smorgasbord of other actors are involved in steering innovation systems. This trend has moved alongside greater calls for accountability of publicly funded projects (such as in NPM) and the growing need to involve the public on issues that may involve risk (Martin, 2016, p. 166).

3.2.4 The inventive unit: Researchers, Teams, Firms and Networks

Alongside the move from linear to systemic thinking has been a move from the unit that R&D and innovation policy attempts to influence. A previous focus had been on the units that produce research: firms, researchers, laboratories etc. Now focus is shifting to various forms of collaborations or multi-actor systems: PPPs, clusters and networks (Martin, 2016, p. 166).

4 Implementation, Institutional and Governmental Change

There exists relatively little literature that considers exactly how R&D or innovation policy is formulated, implemented and the common challenges met along the way. Here we gather some of that which is available and scan the literature for solutions to these issues.

This section will be built upon after the workshop to include the primary research we have conducted and to better tailor to the UAE national context.

4.1 Challenges in Priority Setting

Having a firm rationale is key to aligning the necessary actors. However, creating a rational that is compelling, yet widely accepted may be a challenge.

4.2 Challenges in Implementation

Implementing STI, Innovation and R&D policy can be challenging, especially when there are not great existing domestic research capacities.

The implementation of STI policy may be on a very sectoral basis. But there need to be mechanisms in place to allow the coordination of these (Oyewale, Adebowale and Siyanbola, 2013).

4.3 Challenges in Institutional Reform and cooridnation

The challenge is not only in guiding institutions but managing the interactions in existing institutions. For example, in Nigeria, the implementation of STI policy was hampered by the lack of cooperation between ministries (Oyewale, Adebowale and Siyanbola, 2013). Discontinuities between governments can also be a challenge as long term incentives can be disrupted and the agenda setting work done during policy formation can be disrupted.

Better coordination can be achieved with the use of a number of instruments to coordinate both from national to local levels and across themes. The Basque Country, a region of Spain, is notable for its successful application of instruments such as these to overcome issues associated with conflictual agencies. It utilised a “coordination mix” of instruments such as agencies, networks, business associations (Magro, Navarro and Zabala-Iturriagagoitia, 2014)

STI policy poses a number of unique issues as it overlaps with other areas of policymaking such as economic policy, foreign policy, agricultural policy and education policy. Figure 7, adapted from Margo et al, illustrates the layers of governance to coordinate, both horizontally (across themes) and vertically (across levels of government) .

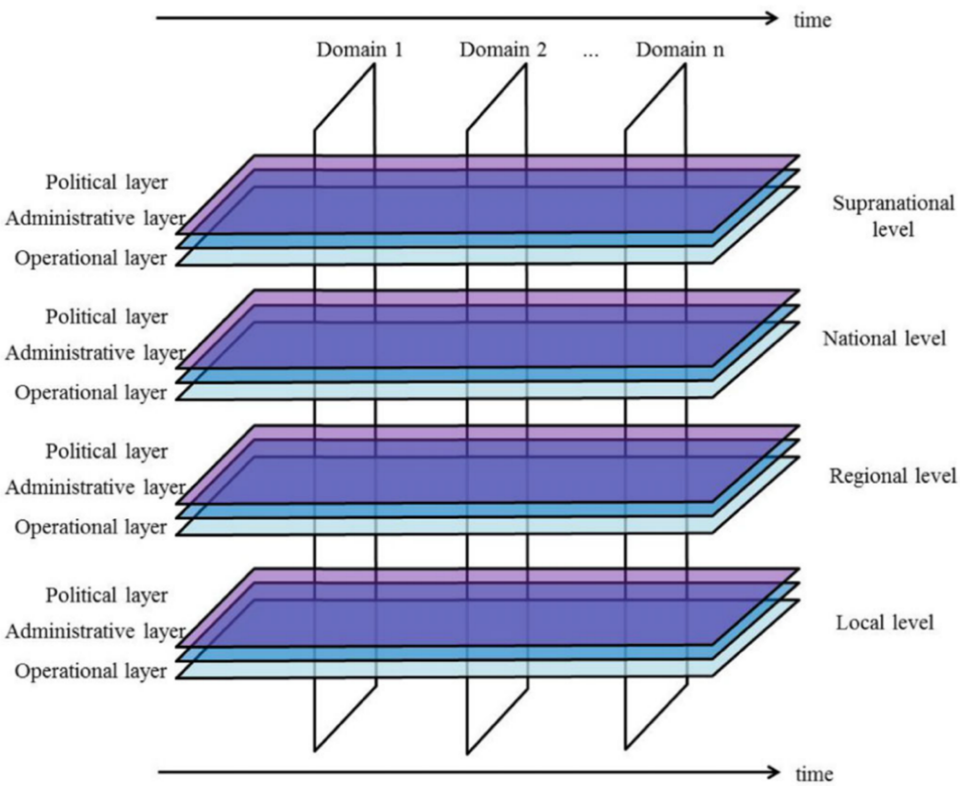

Figure 7: Layers of complexity in STI policy. Taken from Figure 1 in (Magro, Navarro and Zabala-Iturriagagoitia, 2014)

5 Measurement and Monitoring of Outcomes

5.1 Why Monitor?

As has hopefully been conveyed earlier in this primer, the process of policymaking for STI and R&D policy involves interacting with a complex system with a wide variety of stakeholders. As such the relationships between policy inputs and system responses can be complex. For effective programmes it is recommended that programmes monitor their success to determine if they are having the desired outcome and to guide amendments to these programmes. However, there are pitfalls in approaches that focus on narrow indicators that do not properly represent success.

5.2 How is R&D, Innovation monitored?

5.2.1 Input Metrics

These are metrics that measure the levels of financial or human capital going into theR&D system.

These include: % GDP spent on R&D funding, Number of researchers per million population

5.2.2 Intermediate Metrics

These are metrics which indicate the level of research production, but pre-commercialisation.

These include: Patents produced

5.2.3 Output Metrics

These measure new economic activity brought about as a result of innovation.

These include: Numbers of new Products brought to market

5.2.4 Frameworks

A number of prominent frameworks exist for collecting data on and measuring innovation at a national scale, such as the Olso framework (OECD and Eurostat, 2005) and the Frascati manual[26] (OECD, 2015). These frameworks have been heavily used and are very standardised providing a standard candle for comparisons across nations and regions.

[26] Possibly the most well known system

There is also the National Innovation System approach which recommends monitoring information flows between actors, such as:

- Flows between firms (e.g. patent transfers)
- Flows between firms and public institutions (e.g. number of firm-university collaborations)
- Diffusion to companies
- Mobility of technical personnel

However, as these relationships can be complex, the NIS method is not as developed as the Oslo or Frascati and there are fewer cross-national comparisons (Hao, van Ark and Ozyildirim, 2017).

6 National Models of R&D policy and Innovation

This section considers the role of national models. It does so from two perspectives. Firstly, it takes a brief look at some case studies to illustrate how the idea of national models can be seen shaping R&D and Innovation policy in a number of countries. One should recogniss that some level of replication is always inevitable, but wholesale imitation of policy portfolios is likely undesirable.

Secondly it considers the re-application of set models to a number of other nations- in essence is borrowing and appropriating models of innovation systems from other contexts effective? What are the advantages and pitfalls of such an approach?

6.1 Policy Importation/Replication as a practice

Policy Importation is the practice of taking elements and policies or whole systems and attempting to transplant them into a different national context. Practices such as this have been commonplace in the GCC. For example, in the realm of education policy the idea of importing models from elsewhere, such as Singapore, Finland and the UK, was seen as an innovative practice by many GCC nations (Kirk, 2015). However, by importing frameworks and adhering to them rigidly, factors that are unique to the nations particular context.

6.2 The Importation of National policy models

Given the success of many national systems of innovation and one's ability to survey their benefits and weaknesses, it may be tempting for a policymaker planning R&D and Innovation system reform to consider the importation or reapplication of successful schemes. This importance of learning from other national contexts and developed economies on economic policy has been emphasised since the 1800s (Varblane, 2012, p. 1) Much of the existing analysis focusses on

- Institutions
- Actors, networks
- Knowledge, technologies

6.2.1 R&D Policy Importation/Replication

Policy importation has taken place for many years in the area of R&D policy and even countries such as the United States are not immune to it: in the early days of the American state, there was an attempt to copy elements of the German research system and in the 20th century the US copied the of large-scale public finance models for research of other European countries.

Replication can take place form the simple copying of the mechanisms of instruments to attempts to import carbon-copy instruments. Clearly the former is commonplace- there is no need to reinvent the wheel overtime a policymaker develops a policy intervention. On the other hand, the very idea of a national innovation system is a comparative concept, meaning there is no one set model that can be transplanted wholesale (Varblane, Dyker and Tamm, 2007, p. 108), thus all replication is on a spectrum. The question is how successful can more widespread replication be?

Informative examples of what happens when policymakers attempt to replicate innovation systems can be found in Eastern Europe both after the fall of the Iron Curtain and upon the entry of many states into the EU. Upon the integration of New member States (NMS) to the European Union, there was a strong belief in the linear innovation model (frame 1) (Varblane, 2012, p. 7). Produced by these countries focussed mainly on the creation of new high-tech industries and policymakers in many NMS believed that simply focussing on particular high-tech sectors and pouring in money, there would be successful R&D, innovation and growth.

This bias towards certain high-technology sectors was ultimately unsuccessful. This is because there was a mismatch between R&D and education policy: without an alignment between Human Capital development and the research system, it will be difficult to meet industry needs. Thus NMSs fell into a trap of policy imitation, but without analysis (Varblane, 2012, p. 9). Varblane argues that some of blame for this lies with the NMSs acceptance of mediocre advice from the IMF and the bland mix of policies

Another issue with these replications of policies is that they were not implemented. The copying of supermarket-style policies took away much of the necessary emphasis on local capacity building and evaluation (Varblane, 2012, p. 11).

The next subsection explores why naïve policy imitation in the area of STI be additionally problematic: it fails to pay attention to the particulars of national context.

6.2.2 The Intractability of National context

When forming policy focus on the institutions in the 'triple helix'[27] may be too narrow. Understanding the context in which R&D and Innovation is taking place requires an analysis that includes the religious, cultural, scientific, and entrepreneurial culture that surrounds the institutions (Varblane, 2012, pp. 2–3). One must also pay attention to economic systems, education and research systems and political systems (Varblane, 2012, p. 4)

So why is context so critical to evaluation of policy replication? Consider this rather forced metaphor: Much like the transplantation of a plant into a new soil bed must take into account he moisture content of the soil, the acidity of the soil, the shade and the rainfall, if you transplant institutions into a different context, they may not thrive successfully.

[27] Of business, academia and policy. See the second framing

Path dependent processes are at play which mean that economic, cultural and social development paths must be taken into account. Much international experience and research on STI policy focusses on developed economies with a strong knowledge base (Varblane, 2012, p. 5). Path dependency means these experiences cannot be wholly transplanted.

6.2.3 Replicating STI policy: some relevant notes for the UAE context

There are a number of nascent lessons that can be drawn together for the UAE context from the existing literature. Some of these are briefly detailed here, though more contextual exploration will be developed in the final report, taking into account experience from the workshop.

Paying attention to National Context

States should consider what makes their knowledge base unique (Varblane, 2012, p. 17). Often precursor industries can be developed and expertise be transferred to new industries (an example being the attempted transfer from offshore oil and gas to offshore wind in the North Sea).

Resisting the temptation to de-specialise towards voguish industries

Strategic importance is often given by some nations in a knee-jerk way to fashionable technologies such as bio, nano- and info technologies (Varblane, 2012, p. 17), It can be better to think more broadly about what sectors are genuinely most advantageous to support.

Developing Human Capital Alongside STI policy

Bell and Pavit (1997) say you can't just build the plant- you have to absorb the technology. Absorptive capacity requires attention to human capital. Latecomer countries don't just face technology divide, but a learning divide (Varblane, 2012, p. 7).

A vision to develop a diverse knowledge base is needed.

Developing Institutions Alongside STI policy

Ne cannot neglect the role of active learning in developing the innovation system (Varblane, Dyker and Tamm, 2007, p. 107)

Latecomer countries don't just face technology divide, but a learning divide (Varblane, 2012, p. 7)

FDI must be used as a knowledge transfer mechanism (Varblane, 2012, p. 8)

The benefits of being a latecomer

There are a number of advantages to being a latecomer[28] economy as cointries can capitalise on technologies that already exists and avoid some of the risks associated with being a first mover. Paying attention to these advantages is widely appreciated as being of great importance. Latecomer advantages involve (Varblane, 2012, p. 5): (cite A Gerschenkron 1962)

- Acquisition of technologies at lower costs
- Inward investment and the recruitment of skilled people
- Skipping of certain stages of technological development
- Take advantage of markets created by others (don't face uncertainty of making markets anew)

This latecomer advantage is not automatic and according to Abramowitz (1994) relies on

- Technological congruence: how similar are the leader and catcher in terms of market size, factor supply
- Social Capacity: the capabilities of the country for catching up

6.3 Illustrative Case Studies

This section details two brief informative case studies of catching-up countries and their national innovation systems.

6.3.1 National Snapshot: Estonia

The example of Estonia shows a nation that attempted, unsuccessfully to replicate much of another nations R&D system (Finland). However, later efforts to focus on Estonia's strategic position were more successful.

Until second half of 1990s Estonia had what is described by some as a 'no-policy' policy with respect to STI (Varblane, 2012, p. 11). Estonia then began looking to its Baltic and linguistic neighbour, Finland. Such an approach made some sense as the two nations share much cultural and economic history: Estonia has a long history of receiving Foreign Direct Investment (FDI) from Finland and there had even been small aspirations from some to see unification between the two countries in the early 20th century.

Initially the Estonian government made two plans: the *Estonian State Innovation Programme* and the *National Development Plan for 2000-2002*. However, these plans never reached implementation as policymakers didn't pay attention to the different in starting points of the

[28] Not in a pejorative sense. In the sense that the STI system is less established

two countries: Estonia recovering form communism and Finland as an established high-GDP country.

The Estonian parliament passed an R&D strategic plan by end of 2001 (Varblane, 2012, p. 12). This plan proposed a list of sectors to support: user-friendly IT, biomedical sciences and material science. Such a broad and loosely defined list of sectors to support was similar to those of larger nations and did not pay attention to fact that the Estonian economy was not geared up the perform this research. The Estonian economy did not have strong research capacity. So as R&D despecialised with a focus on broad themes,

The plan further suffered from non-realistic targets that focussed on increasing R&D expenditure as a percentage of GDP. The risk such targets is that as nations increase R&D expenditure as a share of GDP, they also tend to see the share of R&D financed by private industry increasing. Thus such a target is difficult and costly to force through

Estonia has seen greater success in developing its R&D sector in recent years thought context-appropriate innovation. In particular they have developed their oil-shale[29] industry , long existing since the 1920s (Varblane, 2012, p. 19). This was brought about in part by their state oil company (EESti Energia) brought in a forward-thinking management team. This R&D came in close collaboration with the Tallinn University of Technology, developing cleaner technologies for the extraction of oil from oil shale.

6.3.2 National Snapshot: South Korea

Perhaps the three of the greatest national economic success stories of the past 50 years are South Korea, Singapore and Taiwan. Emerging from the devastation of the Korean war, South Korea (henceforth simply Korea) was one of the poorest nations on Earth, relying on subsistence farming. In a phases known as 'compressed growth' has quickly caught up with developed nations to become one of the world's most prosperous nations (Lee, Im and Han, 2016).

The Korean success story in terms of STI policy is one that demonstrates the importance of learning and building local capacity and avoiding over-reliance on models drawn from outside of the country.

During the initial phase of Korea's STI deveoment there was a deliberate and concerted focus on developing local expertise and know-how. This involved not simply the usual route of promotion of FDI, but the importation of turn-key factories (to be run by Korean companies), then expansion by local talent (Feinson, 2003). Rather than imply acquiring technologies they went the hard route with an effort to find mechanisms where capital goods could be imported and later reverse engineered.

[29] Not to be confused with "shale-oil" which is associated with hydro-fracking

An example of this absorptive capacity building is the acquisition of badly-needed telecommunications technology from Erikson. Korea ensured that local engineers were involved at all stages of the process of building the national telecoms system. Much of this expertise eventually went to benefit local company Samsung. This is in contrast to nations such as Uruguay, who acquired the same technology form the same company at the same time and failed to incorporate the expertise into their national knowledge base.

Assimilation of technical expertise was further supported with locally-appropriate measures, such as tax breaks and exemptions from military service for certain personnel (Feinson, 2003).

Policymakers also initially focussed on supporting R&D into goods with a short cycle time (such as IT systems). These have lower latecomer barriers as expertise can be built more rapidly and there would be a lower reliance on the expertise bases of established countries. This also facilitates the creation of niche markets. Though some of this pursuit of short cycle life industries was the result of policymakers looking forwards to opening up as many emerging markets as they could (Lee, Im and Han, 2016).

An outward export-orientated in their production systems meant that firms were forced to maintain competitive edge through R&D. To allow smaller firms to compete they established strategic industries exempt from taxes. They balanced the removal of special protections to incentive firms to innovate, without exposing them to early international competition. (Feinson, 2003)

All of this was undergirded with a strong education system to develop human capital, in fact a significant proportion of South Korea's national budget was spent on education, raising literacy rates to need 100% from around 21% after the Korean war (Feinson, 2003)

This rise in econmic productivity came with it a rise in wage rates, leading in the 1980s to something known as the *middle income trap* where the prices of its products increased and it struggled in competition with other East Asian countires (Lee, Im and Han, 2016). A stall in the innovative nature of its products meant that they were unable to adequately differentiate Korean products from equivalent cheaper products made in countries with lower wages. Taiwan and South Korea escaped this trap with further investment in R&D from the 1980s. This stimulates private R&D to surpass publiclly funded R&D (Lee, Im and Han, 2016).

In recent times Korea has experienced another slow-down in economic growth rate. Some reserachers have attributed this to attributed to the focus on the *Chaebols*[30] and the focus on export growth, whilst leaving behind SMEs.

[30] Large state-linked Korean firms such as Samsung

7 Summary

This primer has provided an extremely broad overview of many of the key areas of concern in the process of creating STI policy. Using the policy cycle as a framework it firstly laid out what are the key narratives that have floated over thinking about R&D and Innovation over the last century. These narratives and other ideas are key for the rationales that policymakers build to support policy interventions. With a clear rationale for action, policy can be shown to have a clear direction and help organise actors within an innovation system.

The next phase of the report gave an overview of the typical instruments used to support STI. Financial instruments, such as tax breaks, have been the most popular. The instruments available to support research, development and innovation are by far not only limited to instruments relying on large capital expenditure. Practice and research over the last few decades has shown the value in instruments that facilitate the coordination, learning and interactions between stakeholders in the innovation system.

In producing STI policy a number of trade-offs may be experienced. The eventual mix of policy may be in part influence by the style of administration and governance preferred by policymakers. Assessing the impact of mixes of policy is non-trivial due to the complex interaction between the multitude of participants in an innovation system. However, monitoring can be carried out using a variety of metrics and highly standardised processes, such as those designed by the OECD.

When selecting policy mixes, the experiences of a number of countries can be taken into account. However, the literature cautions against wholesale copying of policy portfolios as this can lead to misalignment with local capabilities. Instead, tailored policies that pay attention to group local intellectual capital bases are favoured.

This primer serves as a basis for discussion, provides a common language to discuss ideas in this policy space and as background setting for the final reports. This report does not reflect the opinion of the UCL STEaPP or the UAE Office of Advanced Sciences. It provides an overview of a number of different strands of thinking.

Key Terms and Acronyms

Additionality	Change in R&D Spending per unit of tax relief
Co-creation	A process where different parties negotiate, formally or informally, a mutually desired outcome
Crowding Out	Where government-funded research may have a knock-on effect of reducing private resaearch
FDI	Foreign Direct investment
Invention	The creation of a new idea
Innovation	The development of new ideas into products, goods or services
Diffusion	The spreading of the use of the innovation
Ex-post	After the fact
HE	Higher Education
NATO System	A system of policy instrument classification: Nodality, Authority, Treasure, Organisation
New Public Management	A movement in public administration emphasising marketisation and goal setting. See section 1.5
NESTA	National Endowment for Science, Technology and the Arts: a UK foundation that promotes innovation through partnerships and other mechanisms
NIS	National Innovation System
NMS	New Member States (of European Union)

NSF	National Science Foundation- US government agency that supports around ¼ of federally funded basic research in the US
NPM	New Public Management
NTBF	New Technology Based Firms
PPP	Public Private Partnership
PTP	Public Technology Procurement
QUANGO	Quasi-Autonomous Non-Governmental Organisation
Rationales	Framings and narratives can provide justification for policy actions through rationales
RDI	Research, Development and Innovation
SME	Small and Medium Sized Enterprise
Social Return	The value of a good to society at large
Socio-technical Transitions	The process in which new technologies are incorporated into society, and society re-adapts itself with the new technology
Spillover Effect	Where the research of one organisation indirectly benefits other organisations. Such effects can benefit innovation and research systems as a whole, but reduce private returns for the organisation conducting the research.
STI	Science, Technology and Innovation

References

Boer, H. de *et al.* (2015) *Performance-based funding and performance agreements in fourteen higher education systems*. Enschede, Netherlands.

Bush, V. (1945) *Science, the endless frontier; a report to the President on a program for postwar scientific research*. Washington, DC, USA.

Chesbrough, H. W. (2003) *Open Innovation: The NEw Imperiative for Creating and Profiting from Technology*. Boston, Massachusetts: Harvard Business School Press.

Cohen, W. M. and Levinthal, D. A. (1990) 'Absorptive Capacity : A New Perspective on Learning and Innovation', *Strategic Management Journal*, 35(3), pp. 128–152. doi: 10.1177/0149206310369939.

Doern, G. B. and Stoney, C. (2009) 'Federal Reserach and Innovation Policies and Canadian Universities: A Framework for Analysis', in Doern, G. B. and Stoney, C. (eds) *Research and Innovation Policy: Changing Federal Government-University Relations*. Toronto: University of Toronto Press, pp. 3–34.

Eakin, H. *et al.* (2011) 'Public sector reform and governance for adaptation: Implications of new public management for adaptive capacity in Mexico and Norway', *Environmental Management*, 47(3), pp. 338–351. doi: 10.1007/s00267-010-9605-0.

Feinson, S. (2003) *National Innovation Systems Overview and Country Cases*. Colombia University, NY, USA.

Ferlie, E., Musselin, C. and Andresani, G. (2008) 'The steering of higher education systems: A public management perspective', *Higher Education*, 56(3), pp. 325–348. doi: 10.1007/s10734-008-9125-5.

Görg, H. and Strobl, E. (2007) 'The effect of R&D subsidies on private R&D', *Economica*, 74(294), pp. 215–234. doi: 10.1111/j.1468-0335.2006.00547.x.

Guellec, D. and Van Pottelsberghe De La Potterie, B. (2003) 'The impact of public R&D expenditure on business R&D*', *Economics of Innovation and New Technology*, 12(3), pp. 225–243. doi: 10.1080/10438590290004555.

Hall, B. H. and van Reenen, J. (1999) *How Effective are Fiscal Incentives for R&D Policy?* 7098. Cambridge, MA, USA. Available at: http://www.nber.org/papers/w7098.

Hao, X. (Janet), van Ark, B. and Ozyildirim, A. (2017) *Signposts of Innovation: A Review of Innovation Metrics*, *Economics Program Working Paper Series*. New York, NY, USA. doi: 10.2139/ssrn.2970648.

Haque, M. S. (no date) 'New Public Management: Origins, Dimensions, and Critical Implications', in *Public Administration and Public Policy*. Encyclopedia of Life Support Systems.

Herstad, S. J., Bloch, C. and Ebersberger, B. (2010) 'National innovation policy and global open innovation: exploring balances, tradeoffs and complementarities', 37(March), pp. 113–124. doi: 10.3152/030234210X489590.

Himanen, L. *et al.* (2009) 'Influence of research funding and science policy on university research performance: A comparison of five countries', *Science and Public Policy*, 36(6), pp. 419–430. doi: 10.3152/030234209X461006.

Hottenrott, H. and Lopes-Bento, Ci. (2012) '(International) R & D Collaboration and SMEs : The effectiveness of targeted public R & D support schemes', *Research Policy*, 43(6), pp. 1055–1066.

Howlett, M. (2011) 'Understanding contemporary policy designs', in *Designing Public Policies Principles and instruments*. Taylor and Francis, pp. 127–159. Available at: www.eBookstore.tandf.co.uk.

Howlett, M. and Fraser, S. (2009) 'Government communication as a policy tool a framework for analysis. Canadian Science Review', 3(June), pp. 23–37.

Jongbloed, B. *et al.* (2018) 'Performance Agreements in Higher Education: A New Approach to Higher Education Funding', in Curaj, A., Deca, L., and Princopie, R. (eds) *European Higher Education Area: The Impact of Past and Future Policies*. Bucharest, Romania: Springer Open, pp. 671–687.

Khan, S. S. *et al.* (2016) 'The framing of innovation among European research funding actors: Assessing the potential for "responsible research and innovation" in the food and health domain', *Food Policy*, 62, pp. 78–87. doi: 10.1016/j.foodpol.2016.04.004.

Kirk, D. (2015) 'Innovate or replicate? Education reform initiatives in the Gulf cooperation council states', *Muslim World*, 105(1), pp. 78–92. doi: 10.1111/muwo.12081.

Kleinman, D. L. (1995) *Politics on the Endless Frontier*. Durham, NC, USA: Duke University Press.

Köhler, C., Larédo, P. and Rammer, C. (2012) *The Impact and Effectiveness of Fiscal Incentives for R&D*, *NESTA Compendium of Evidence on Innovation Policy Intervention*. 12/02. Manchester,Uk. Available at: http://www.innovation-policy.net/compendium/.

Kuhlmann, S., Smits, R. and Shapira, P. (2013) 'Introduction. A Systemic Perspective: The Innovation Policy Dance', in *The Theory and Practice of Innovation Policy: An International Reserch Handbook*. Cheltenham, UK: Edward Elgar. doi: 10.4337/9781849804424.00006.

Laranja, M., Uyarra, E. and Flanagan, K. (2008) 'Policies for science, technology and innovation: Translating rationales into regional policies in a multi-level setting', *Research Policy*, 37(5), pp. 823–835. doi: 10.1016/j.respol.2008.03.006.

Lee, K., Im, B. and Han, J. (2016) 'The National Innovation System (NIS) for the Catch-up and Post-Catchup Stages in SOuth Korea', in *The Korean Government and Public Policyt in Development Nexus: Sustainable Development and Tackling Policy Challenges*. Springer, pp. 1–22. doi: 10.1007/978-3-319-52473-3_10.

Magro, E., Navarro, M. and Zabala-Iturriagagoitia, J. M. (2014) 'Coordination-mix: The hidden face of STI policy', *Review of Policy Research*, 31(5), pp. 367–389. doi: 10.1111/ropr.12090.

Martin, B. R. (2016) 'R & D policy instruments – a critical review of what we do and don ' t know', *Industry and Innovation*. Routledge, 2716, pp. 1–20. doi: 10.1080/13662716.2016.1146125.

Mazzucato, M. (2013) *The Entrepreneurial State: Debunking Provate Vs Public Sector Myths*. Anthem Press.

Meissner, D. and Rudnik, P. (2017) 'Creating sustainable impact from Foresight on STI Policy', *Foresight*, 19(5), pp. 457–472. doi: 10.1108/FS-06-2016-0021.

Merton, R. (1942) 'The Normative Structure of Science', in Merton, R. (ed.) *The Sociology of Science: Theoretical and Empirical Investigations*. Chicago, Il, USA: University of Chicago Press.

Nyiri, L. *et al.* (2007) *Public Procurement for the Promotion of R&D and Innovation in ICT*, *European Comission*. Seville, Spain. Available at: http://ftp.jrc.es/EURdoc/eur22671en.pdf.

OECD (2015) *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation*

Activities. Paris, France: OECD Publishing.

OECD and Eurostat (2005) *Oslo Manual. Guidelines for collecting and interpreting innovation data*. Third. OECD Publishing.

Olsen, J. (1988) 'Administrative Reformand theories of organisation', in *Organising Governance: Governing Organisations*. Pittsburgh, USA: University of Pittsburg Press, pp. 233–254.

Oyewale, A. A., Adebowale, B. A. and Siyanbola, W. O. (2013) 'Nigeria's STI policy and the dilemma of implementation', in *Reserach Handbook on Innovation Governance for Emerging Economies*, pp. 345–374.

Peters, B. G. (2000) 'Policy Instruments and Public Management : Bridging the Gaps', *Journal of Public Administration Reserach and Theory*, 10(1), pp. 35–47.

Popp, D. (2010) 'Innovation and Climate Policy', *Annual Review of Resource Economics*, 2, pp. 275–98. doi: 10.1146/annurev.resource.012809.103929.

Robinson, M. (2015) *From Old Public Administration to the New Public Service Implications for Public Sector Reform in Developing Countries, UNDP Global Centre for Public Service Excellence*.

Rosenfeld, S. A. (2002) *Creating Smart Systems: A guide to cluster strategies in less favoured regions*. Available at: http://www.rtsinc.org/publications/pdf/less_favoured.pdf.

Royal Society (2018) 'How does the UK government invest in R & D ?' London, UK, pp. 1–2. Available at: https://royalsociety.org/-/media/policy/projects/investing-in-uk-r-and-d/how-does-the-UK-government-invest-in-R-and-D-07-11-17.pdf.

Sá, C. M. and Litwin, J. (2011) 'University-industry research collaborations in Canada: The role of federal policy instruments', *Science and Public Policy*, 38(6), pp. 425–435. doi: 10.3152/030234211X12960315267732.

de Saille, S. (2015) 'Innovating innovation policy: the emergence of "Responsible Research and Innovation"', *Journal of Responsible Innovation*, 2(2), pp. 152–168. doi: 10.1080/23299460.2015.1045280.

Schot, J. and Steinmueller, W. E. (2018) 'Three frames for innovation policy: R&D, systems of innovation and transformative change', *Research Policy*, 47(9), pp. 1554–1567. doi: 10.1016/j.respol.2018.08.011.

Uyarra, E. and Ramlogan, R. (2016) ‘The impact of cluster policy on innovation’, in Edler, J. et al. (eds) *Handbook of Innovation Policy Impact*, pp. 196–238. doi: 10.4337/9781784711856.00014.

Varblane, U. (2012) *National Innovation Systems : Can they be copied?*, *Ordungspolitische Diskurse: Discourses in Social Market Economy*. 2. Tartu, Estonia.

Varblane, U., Dyker, D. and Tamm, D. (2007) ‘How to Improve the National Innovation Systems of Catching-up economies?’, *TRAMES*, 11(61/56), pp. 106–123. doi: 10.1016/j.laa.2014.09.035.

Wallsten, S. J. (2000) ‘The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program’, *The RAND Journal of Economics*, 31(1), p. 82. doi: 10.2307/2601030.