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The role and impact of innovation agencies: an international review

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Executive summary

This report presents an overview of the scholarly literature and case study data regarding the role of public sector agencies in accelerating technological innovation. The aim is to inform heat decarbonisation policy discussions in Scotland, and the developing plans for a Scottish 'low-carbon heat hub'.

The report is split into three main sections: design principles for innovation agencies; types of innovation agencies; and specific activities of innovation agencies.

Design principles for innovation agencies

This section discusses agency mission, scope, and operational autonomy. Four potential 'policy pitfalls' are highlighted: *information failures*, *political capture*, *lack of accountability* and *lack of strategic clarity*. We also discuss key institutional design principles, such as flexibility and autonomy from private interests, that seek to avoid, or address, these risks and pitfalls.

Case studies of the US Advanced Research Projects Agency – Energy and the UK Energy Technologies Institute are used to illustrate practical design challenges. These examples illustrate tensions in the design of agencies regarding embeddedness, autonomy and accountability, and also regarding flexibility and stability.

The following practical questions for policymakers are presented and discussed with reference to a number of case studies:

- *What is the specific problem that needs to be solved?*
- *Which types of beneficiaries should the agency support to further its mission?*
- *How much autonomy does the agency require to design and deliver its mission?*
- *What resources does the agency need to deliver on its objectives?*
- *What kind of support should the agency provide?*
- *What geographic level should the agency work at?*

- *What systems and processes should be put in place to understand outcomes?*
- *How can an agency's overall value be judged?*

Types of innovation agencies

Based on three factors - agency remit and agenda; institutional structure and capability; and metrics of success - four distinct types of agency are identified: Market & System Fixers, Industry Builders, Mission Drivers and System Optimisers.

Several case study examples are used to illustrate the strengths and weaknesses of different agency types in particular national or regional settings; examples here include the Danish GTS institutes and Sitra, a Finnish innovation agency.

Specific activities of innovation agencies

There are a number of specific activities that agencies undertake, including: foresight and diagnostics; gatekeeping and brokering; testing, validation, and training; accreditation and standards; and intellectual property management. This section includes agencies supporting eco-innovation in German, Swedish and Finnish regional cases studies. One of the key empirical findings from these detailed studies is the division of responsibilities between multiple innovation agencies operating in the same industry or region, with different organisations suited to providing different kinds of support. The analytical frameworks and case studies highlight the importance of tailoring the features of any particular innovation agency to a particular task or role, as well as the need to consider the wider innovation system, and the complementarity of the various support actors working within it.

Overarching themes and conclusions

Persistent issues relevant to the Scottish policy discussion surrounding energy sector transition heat decarbonisation are:

- *The limits of general classification*: the importance of tailoring an innovation agency to meet the particular policy goals, and the strengths and weaknesses of a given region.
- *The need for a system-wide approach**:*** while the design and function of a specific agency is important, it is vital to consider their complimentary role within a wider innovation system
- *The tension between autonomy and embeddedness:* the need to consider the effect that close linkages between innovation agencies and public and private sectors can have on institutional autonomy, and the impact this can have on the balance between urgent policy implementation goals and more emergent and perhaps radical long-term innovations.

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1 Introduction

1.1 The rise of green industrial and innovation strategy

Technological innovation has a long history as a tool for governments and policymakers to address major policy problems. Modern examples range from wartime 'mission-oriented' R&D programmes such as the Manhattan Project, which produced the first nuclear weapons, to the 'Space Race' of the 1950s and 1960s (Foray et al., 2012). Mindful of these historical successes, there is an extensive body of research which argues for similar interventionist policy approaches to address contemporary issues such as climate change, the need for rapid shifts in industrial activity, and stagnant economic growth (Chaminade and Edquist, 2006; Newell, 2008; Rodrik, 2007, 2014; Mazzucato and Perez, 2015).

Perhaps most notably, Mazzucato (2013, 2015) has argued for the need for an 'entrepreneurial state' to tackle high-risk, capital-intensive projects that are often left unaddressed by private sector actors solely guided by market forces. Such an approach, she argues, requires a "new justification of government intervention that goes beyond the usual one of 'fixing market failures'", where the public sector takes an active role in shaping and creating markets (*ibid*., 2015, 1).

However, some scholars assert that a shift towards a 'greener,' more sustainable economy is a distinct form of innovation, and perhaps incompatible with more traditional conceptions of industrial strategy. For example, Alkemade et al. (2011) argue that 'innovation policy' often views economic growth as its prime objective, while 'transition policy' has the broader aim "to drastically change the current production and consumption system" and engender widespread sociotechnical regime change. The authors add that misalignment in terms of ultimate goals can lead to conflicting and inconsistent policies.

Haley (2016) discusses the role of public sector institutions in promoting technological innovation, and the recent trend of governments to play an increasingly active role in industrial strategy. Haley argues that public sector support of technological innovation reflects "a growing policy consensus on the need for more strategic and targeted approaches" to confront larger societal issues like environmental degradation and climate change, and the need for 'clean innovation' whose overall aim is "creating products and/or processes specifically linked to reducing environmental impacts or improving environmental outcomes" (2016, S55). Accordingly, pursuit of a clean innovation agenda requires a 'shift in trajectory' away from more polluting, carbon-intensive technologies and industries towards more sustainable, low-carbon alternatives.

In 2019, the Scottish and UK Governments set enhanced legally binding 'net zero' carbon targets. While these are ambitious, they are part of an international response to better align national policy commitments with international commitments made as part of the Paris Agreement to limit climate change, with many countries setting national net zero targets for around mid-century (Black et al., 2021; ECIU, 2021).

In 2020, the Covid-19 global pandemic forced much of the world's economic system into the deepest recession for a century (IMF, 2020). How the pandemic and its economic consequences affect global efforts to address climate change has been subject to much debate. While a short-term reduction in GHG emissions was clear (Le Quéré et al., 2020), the longer-term effects, from changes in public budgets, economic stimulus

packages and potentially shifting social and political priorities, remain uncertain (Forster et al., 2020; Klenert et al., 2020; Reilly et al., 2021).

In the wake of the pandemic, governments around the world have already developed economic stimulus packages that seek to boost economic growth. National economic stimulus measures have tended to focus on low carbon sectors, and proposals for a 'green recovery' (e.g. Scottish Government, 2020a; von der Leyen, 2021). On a global scale, it has been estimated that forging an economic recovery tilted towards green stimulus and reductions in fossil fuel investments, it is possible to avoid future warming of around 0.3 °C by 2050 (Forster et al., 2020).

At the same time, growing attention to the need for a 'just transition' reflects the potential for climate change mitigation efforts to disrupt existing industries and to lead to job losses and regionally disparate economic impacts (Jenkins et al., 2020). While the loss of jobs from existing fossil fuel industries is acknowledged (Johnstone and Hielscher, 2017), a failure to capture benefits from emerging green industries is also a concern for some regions. For example, while the UK leads the world in offshore wind implementation, there is disquiet at the limited number of associated jobs for UK firms. While securing green jobs and green growth are important for the legitimacy of the net zero transition (McDowall et al., 2013), more local efforts to capture these benefits can give rise to competition between regions, and are not without their risks for communities and policymakers (EEFW Committee, 2021).

1.2 Scottish energy and heat policy context

Scotland has decarbonised faster than many other developed nations (CCC, 2020, pg. 34). Since the Climate Change (Scotland) Act in 2009, emission reductions have largely been achieved by changes in the electricity sector. The growth in onshore and offshore wind energy in the UK has been accompanied by remarkable cost reductions, with the cost of offshore wind falling by almost 75% in five years (Evans, 2019). Increasingly, policy focus is shifting to other parts of the energy economy, notably heating and transport, where progress has been very limited to date. In the context of economic recovery stimulus measures, such plans are framed as local opportunities for low carbon technology commercialisation, alongside green growth and green jobs.

In the low carbon heat supply sector, there is a widespread assumption that technology costs will reduce as market deployment expands, but some technologies are relatively well established internationally, and further capital cost reductions may be modest. More emergent low carbon heat decarbonisation may have greater prospects in terms of cost reduction, but their starting costs are substantial and their prospects uncertain. The contribution of more emergent technologies may also be limited by the sheer pace of envisaged change in the heat sector, with manufacturing, servicing and supply firms facing transformational change in the next 10-15 years.

The Scottish Government has announced a 'national mission to create green jobs' (Scottish Government, 2020a) with job creation and economic development fundamental in the wider narrative of Scottish climate change plans (Scottish Government, 2020b) and sector specific decarbonisation strategies. These are particularly ambitious in the heat and buildings sector. Scotland's 2030 economy-wide target for Scotland of a 75% GHG emission reduction has been translated into a strategy for emissions reductions from buildings by at least 68% by 2030 – probably the most ambitious target for 2030 in Europe. (Scottish Government, 2021; Kerr, 2021).

In Scotland, there is a particular interest in establishing an innovation agency to address the opportunities and challenges of heat sector transition. The Scottish Government's Heat Pump Sector Deal Expert Advisory Group has recommended that Scotland's enterprise agencies work with industry to support Scotland as a global centre of excellence for heat pump manufacture (Scottish Government, 2021b). A recent report for Scotland's three publicly funded enterprise agencies (Optimat / ITP Energise, 2021) called for the creation of a 'low carbon heat hub' based on a portfolio of services including "showcasing and demonstration, skills development, networking and information sharing" (p. 48). More broadly, the Scottish Government has announced plans for a new a National Public Energy Agency to "provide leadership and harness the potential of scaled up programmes to decarbonise heat" (Scottish Government, 2021a, p.3).

1.3 Report aims and outline

This report aims to inform Scottish policy efforts to promote the development of domestic industrial and innovation capacity in the low carbon heat sector. In particular relation to Scottish interest in a potential low carbon heat innovation agency, this report reviews international evidence on the role and impact of innovation agencies. The report covers a broad range of national and sectoral contexts, going well beyond the energy sector. This broad focus reflects early scoping research which found little published research evidence on the effectiveness of innovation agencies specifically dedicated to the low carbon heat sector.

The report ranges in scope from broader to more specific aspects of the work of innovation agencies and covers both prominent analytical frameworks and several case study examples. It is structured into a series of sections on the *design, types* and *functions* of innovation agencies, with a short final section on conclusions and policy recommendations.

- Section 2 considers *design principles for innovation agencies*, including a discussion of general issues to consider in the design and conception of an innovation agency; the section includes case study examples which illustrate the inherent tension between agency autonomy and accountability, on the one hand, versus embeddedness and credibility on the other.
- Section 3 reviews evidence on the *different types of innovation agencies*, with an overview of the various general roles that innovation agencies play in supporting technological development; this section summarises different classifications that analysts have derived to categorise agencies, based on criteria that include mission and scope, overall goals, and their relationship to public and private sector actors.
- Section 4 covers the *specific functions of innovation agencies*, including a more focused look at the specific ways that innovation agencies function within a given innovation system. Making reference to several case study examples, this section includes a discussion of the tension between specificity and breadth of mission, and how an agency's size, structure, and level of resources impacts which roles they can successfully fulfil.
- Section 5, *conclusions and policy implications* considers how evidence from innovation agency research can inform contemporary Scottish interest in an innovation agency to support energy sector transition and heat decarbonisation.

2 Design principles for innovation agencies

2.1 Introduction

Innovation agencies can be powerful tools for policy makers in facilitating a clean innovation shift. Haley (2016) highlights some cases of traditional support roles that are particularly salient to low-carbon innovation, where government intervention can alleviate developmental bottlenecks. For example, governments may adapt training programmes or regulatory standards to meet new industrial needs, or offer 'patient capital'[1] for long-term, high-risk, high-reward technologies that have yet to find market support (Carlsson and Jacobsson, 1997; Block and Keller, 2011; Mazzucato, 2013).

However, public sector involvement in technological innovation can be as much a hindrance as it is helpful. Drawing from examples from the innovation policy literature, Haley identifies four main 'policy pitfalls,' or reasons why government-led innovation initiatives can fall short of their objectives (Haley, 2016, S56; 2017; 108-9):

1. *information failures*: a lack of understanding or information about the technology or industries to be supported
2. *political capture*: the risk of rent-seeking private interests exerting undue influence on overly-receptive governments
3. *principal-agent problems*: the prospect for policy making to be co-opted by an insular bureaucratic elite, with little accountability to the electorate or their representatives
4. *complexity, ambiguity, and risk-aversion*: a broad category, referring to the challenge of using incomplete information to find solutions to problems that are often ill-defined, in the face of competing political priorities and desired outcomes

These four reasons are inter-related. Haley points out that under-informed policymakers are more prone to influence by powerful industrial actors, creating "a situation where the government provides policy support that promotes the industries that are the best at lobbying rather than the best at producing new innovations" (*ibid.*, S56). In a similar vein, while acknowledging that there is little evidence for civil servants selectively filtering information to decision-makers in an effort to avoid political oversight, Haley notes that concerns about the disproportionate influence of civil servants can erode the legitimacy of public-sector agencies in the eyes of the public and industry (Haque, 1996). This can lead to the adoption of a "passive risk-avoidance approach" (Savoie, 2015) in order to avoid unwanted political attention and blame (Hood, 2010).

2.2 Haley's design principles

The main focus of Haley's 2016 work is a discussion of key institutional design principles that seek to avoid, or address, the potential risks and pitfalls described above. These principles, and a brief description, are listed in Table 1 below:

[1] Macfarlane and Mazzucato (2018, 7) argue that "because innovation is highly uncertain, has long lead times, is collective and cumulative, it requires a specific type of finance … [this] kind of finance must be patient".

Table 1: Institutional design principles (modified from Haley, 2016)

Institutional Design Principle	Description
1) ***Comprehensiveness***	Adopting a system-wide consideration of the innovation problem
2) ***Flexibility***	Ability to adapt to new knowledge or shifts in industrial dynamics
3) ***Autonomy from Short-term Political Pressure***	Because innovation is uncertain and failures are normal
4) ***Mission Orientation***	Having a clear purpose and well-defined objectives
5) ***Embeddedness within Policy Networks***	Having strong linkages to government, industry, research institutes, and other actors
6) ***Autonomy from Private Interests***	Using independent and/or in-house expertise and having a clear mission to engage with industry on the agency's 'own terms'
7) ***Competence***	The ability to earn the trust of stakeholders by demonstrating a clear understanding of the innovation problem, and the will and capacity to address it, via the implementation of "stable, sufficient, and predictable" policies
8) ***Credibility***	
9) ***Stability***	
10) ***Accountability***	Agencies must be transparent, operate in the public interest and be subject to political oversight

Referring back to the four main innovation policy pitfalls discussed above, Haley describes the aim of these design principles as being the creation of public-sector institutions that are:

> *Able to access information from multiple quarters yet avoid being captured by private interests; accountable and motivated by contributing to the public good; and nimble, flexible, and cognizant of the unique role government plays in society.*
>
> Haley, 2016, S56-7

With this in mind, Table 2 illustrates which policy pitfall each design principle is intended to address.

Table 2: Policy pitfalls and institutional design (modified from Haley, 2017)

	Information failure	Political Capture	Principal-agent problems	Complexity, Ambiguity, Risk Aversion
Comprehensiveness	•			•
Flexibility	•		•	•
Autonomy from Short-term Political Pressure				•
Mission Orientation			•	•
Embeddedness within Policy Networks	•			
Autonomy from Private Interests		•		
Competence	•	•		
Credibility				•
Stability	•			•
Accountability			•	

2.3 Design principles: case studies

To illustrate the design principles and policy pitfalls involved, Haley (2017) and Watson (2021) consider case studies of energy innovation agencies. While acknowledging the challenges of implementing any one of these design principles in isolation, both authors also note the inherent tensions, and even contradictions, that can arise between principles.

2.3.1 Advanced Research Projects Agency – Energy (ARPA–E)

This case study illustrates the inherent difficulty in striking a balance between autonomy and accountability when designing a public sector innovation agency.

Haley's (2017) analyses the Advanced Research Projects Agency – Energy (ARPA-E) in the United States. ARPA-E was founded in 2007 under the aegis of the US Department of Energy, and was charged with promoting "high potential, high-impact energy innovations," in an effort to "improve US economic competitiveness, energy security and reduce greenhouse gas (GHG) emissions" (ibid, 115). The agency's relatively small staff of 56 was tasked with managing short-term, 1-3 year projects, the cost of which is shared between ARPA-E and its partners drawn from universities, national labs, private corporations and non-profits.

Haley highlights some elements of ARPA-E's operation that align with the institutional design principles described above. For example, ARPA-E is distinct from other US government energy agencies, in that it is explicitly *'mission-oriented,'* concentrating on focussed innovation projects, rather than the wider energy system. Similarly, programme directors and many senior staff members serve relatively short 3-5 year terms, which Haley also argues helps maintain a clear institutional focus on discrete, achievable goals. *Flexibility* is also a key feature of ARPA-E operations: the contracts and procurement process are allowed to function outside of normal government channels, and administrators were given wide latitude regarding staffing and hiring procedures; this latter point is also held to be an enabler for a high level of *competence* and *credibility* within the organisation. In a similar vein, while their terms of office are relative short, ARPA-E administrators have significant latitude to develop and pursue their own innovation agenda largely *free from political pressure,* which Haley argues is also an effective means of promoting *autonomy from private interests,* and ultimately one of the agency's greatest strengths.

However, ARPA-E does illustrate some significant tensions between Haley's institutional design principles. For example, the short project timelines and the relatively quick turn-over of leaders and high-level staff does create some problems with *stability,* as the focus and direction of the agency has the potential to shift relatively quickly; this also erodes overall *accountability* to political oversight, and *credibility* with industrial partners. These points are further exacerbated by wider financial issues, as ARPA-E is subject to annual budgetary oversight from both the US Congress and the office of the President. Indeed, the continuity of funding – and indeed mission – has thus far been subject to capricious political whims regarding the importance renewable energy issues in the US (*ibid.*, 119). These points illustrate what to Haley is the enduring message from the ARPA-E case study: namely, the inherent difficulty in striking a balance between autonomy and accountability when designing a public sector innovation agency.

2.3.2 Energy Technologies Institute (UK)

This case study illustrates tensions between embeddedness and autonomy from policy and private interests when designing a public sector innovation agency.

Watson (2021) examines the role of the UK Energy Technologies Institute (ETI), which operated between 2007 and 2019. The overall mission of the ETI was similar to that of ARPA-E, focussing on supporting the renewable and low carbon energy technology sector. In order to achieve this, the ETI aimed at bridging the 'valley of death' between early-stage research, largely done by universities and the public sector, and market-ready technologies ready for deployment by private industry.

Sitting at arm's-length from the UK Government, the governance of the ETI was handled by a board comprising the Institute's six industry partners (including large energy conglomerates British Petroleum, Electricité de France, and Shell), as well as representatives from public sector actors such as Innovate UK, the Engineering and Physical Sciences Research Council (EPSRC) and the Department of Business, Energy, and Industrial Strategy (BEIS). Out of the £60m annual operating budget, £5m was provided by each of the private sector partners, with these funds being matched 50:50 by the UK Government.

While noting that the ETI was framed as "the most important [development] in UK energy research and innovation for decades" (DTI, 2006, 2), Watson also situates the organisation within a shift in the UK policy landscape that occurred in the early 2000s, coinciding with establishment of both the UK Energy Research Centre (UKERC), and the Carbon Trust; these agencies were part of a larger trend towards supporting technology

innovation as a means of achieving ambitious climate and energy decarbonisation policy goals.

Positive design features

Watson's analysis of the ETI evaluates its overall impact supporting technology innovation in terms of the 10 institutional design principles outlined by Haley (2016, 2017). For example, the agency was considered to be highly *stable:* partners were contracted for a 10-year period and were required to offer 2 years notice – and forfeit any additional project outputs – if they wished to exit early.

Furthermore, in view of the perceived urgency around climate change policy targets, the decision to structure the ETI as a public-private partnership (PPP) entity ensured that the agency was well *embedded within policy networks,* allowed it to take advantage of the "engagement and influence of large energy companies," which also bolstered its overall *credibility* with the private sector.

Watson also notes that the involvement of a range of actors from both the private and public sectors improved the overall *comprehensiveness* of the agency. According to former staff from ETI and government, this design choice was made in an effort to replicate the success of the Carbon Trust, whose 'arm's length' PPP structure had been successful at bringing together stakeholders from a diverse group of stakeholders in education, health, and transport (Kern, 2009, 2012; Lam and Javed, 2015).

Pitfalls and criticism

Watson points to numerous shortcomings with the structure and operations of the ETI, which she frames as tensions between several of Haley's institutional design principles. Central to these criticisms is the PPP structure itself, and how the intimate involvement of industrial actors within the decision-making and governance process of the ETI inescapably weakened the agency's *autonomy from private interests*, and ultimately blunted its pursuit of overall *mission*. Watson describes a persistent mismatch between aggressive policy goals from government that pushed towards more speculative, higher-risk funding priorities, and the inherent conservativism of ETI's corporate partners, who favoured lower risk, less ambitious projects and technologies (ibid, 185).

Watson also suggests that the ETI also struggled to exert *autonomy from short-term political pressure*, as both the public and private sector actors pushed for the agency to privilege support for UK-based firms and technologies, a practice which intensified following the 2008 financial crisis. The embeddedness of a select group of private sector actors coupled with the close involvement of numerous government departments, and the consequent pressure towards 'market-distortion', eroded the ETI's overall *credibility* in the eyes of the wider energy industry. Indeed, aside from issues of favouritism or a lack of impartiality, Watson reports that some firms were reluctant to become more involved with the ETI due to concerns about the security of their IP and proprietary technologies (*ibid.*, 185). It is interesting to note, given the conscious decision to model the ETI on aspects of the Carbon Trust, that concerns over intellectual property rights was also cited by some private firms as a barrier to engagement with that latter agency (Winskel, 2007).

Finally, Watson notes that the inclusion of a range of leading energy firms, while intended to provide a diverse range of perspectives and competencies to the agency, ultimately undermined the ETI's level of *comprehensiveness*, as a focus on the engineering and physical science aspects of renewable energy projects inevitably came at the expense of other, less technical kinds of knowledge and expertise. While this sophisticated technocratic approach did guard against what Watson refers to as

unwarranted "technology hype," it also reduced the overall *competence* and *accountability* of the agency, leading to the perception that the ETI was a "closed shop" and hindered efforts to engage and communicate with stakeholders outside a relatively small core of policymakers and industrial actors. Notably, the ETI conceded many of these points in a review report published near the end of its tenure (ETI, 2018, 42-3), raising the possibility that it would have been more responsive to a broader range of stakeholders had the organisation continued.

2.4 Refining Haley's design principles

Building off the points illustrated by the ETI case study, Watson offers some critiques of the 10 institutional design principles initially proposed by Haley. Chief amongst these is a refinement of the role of industry *embeddedness*. Watson argues this is based on emergence of the IT sector (Evans, 2012), and thus less appropriate for dealing with a "legacy sector" like energy and may indeed hamper the adoption of policies that target accelerated innovations (McMeekin et al., 2019; Markard et al., 2020). Instead, Watson suggests that more care must be taken to when deciding *which* private sector actors to involve in the policy development process. Their outlook and priorities should be congruent with the innovation agency's overall mission and goals, as well as the overall policy goals at a governmental level.

In a similar vein, Watson calls for a more nuanced understanding of the principles of *competence* and *flexibility*. Regarding *competence*, the case of ETI illustrates how the dominance of one kind of actor, with a particular skillset and knowledge base, may lead to other kinds of expertise or competencies being overlooked or under-represented. While Haley's understanding of institutional *flexibility* focussed largely on being open and responsive to changing technological and market conditions, Watson points to the need for innovation agencies to be less rigid in their own internal operations. For example, data collected during the case indicated that the ETI showed a lack of operational flexibility in its interactions with potential partners like SMEs and non-profit organisations, who often struggled to meet "strict, pre-prescribed project criteria" that were more tailored to larger energy and technology firms.

Overall, Watson's analysis of the ETI presents a picture of an agency that was the product of the broader energy system at the time of its formation. Its heavily embedded structure meant that its operations and ultimate outputs were closely in line with the interests of incumbent private sector actors, who gravitated towards supporting research and technologies that would be competitive within the existing energy system. In Watson's view, this approach precluded deeper engagement with more disruptive actors and higher-risk projects, ultimately blunting the agency's nominal mission of supporting innovative new technologies for the UK's energy system.

2.5 Key design components

In a report for the UK innovation agency, Nesta, Glennie and Bound (2016) also address the issue of how to design an innovation agency. Instead of following Haley and Watson focusing on specific principles, Glennie and Bound propose eight practical questions for policymakers to consider when designing an innovation agency. Based on observations from extensive case study examples, these questions are grouped together as pairs addressing four crucial design components**, *Mission, Management, Methods, and Metrics***, which the authors argue are foundational to the structure and operation of any

innovation agency (*ibid.,* 2016, 28). These are now considered in turn, with practical examples.

2.5.1 Mission

- *What is the specific problem that needs to be solved?*
- *Which types of beneficiaries should the agency support to further its mission?*

Clearly, a poor understanding of the problem to be solved or an agency with an ill-defined purpose are both likely indicators of policy failure. However, Glennie and Bound highlight the risks of emulating institutions and programmes that have proven to be successful in other industries or geographic regions. Not only is it important to tailor a policy response to fit the specific strengths and weaknesses of a given industry or geographic region, but different end goals will require different policy responses and institutional structures, which may imply focussing on supporting very different kinds of actors.

To illustrate this point, the report discusses the ***Israeli Office of Chief Scientist (OCS),*** a relatively small organisation which was tasked with raising the overall level of private R&D activity across the entire economy, and consequently targeted a variety of firms of varying sizes from numerous industrial sectors, aiming to build partnerships with a host of universities and public sector research institutes. The OCS is presented in contrast to *the* ***Industrial Technology Research Institute (ITRI)*** in Taiwan, an agency focused on modernising that nation's economy through the creation and support of specifically targeted high-technology sectors. As Glennie and Bound (2016) note, the different missions of these two agencies prompted "the creation of quite different types of institution in terms of the criteria for success, beneficiaries, budget, management structures, the types of expertise held within the organisation and the methods and instruments used" (*ibid.*, 29).

2.5.2 Management

- *How much autonomy does the agency require to design and deliver its mission?*
- *What resources does the agency need to deliver on its objectives?*

Institutional autonomy is one of the more persistent issues related to the design and operation of innovation agencies. As discussed above, these issues can arise not only as the result of excessive private sector influence or 'policy capture', but also due to pressure exerted by politicians and the public sector, as Watson (2021) illustrated with the case of the ETI and its support for UK-based business amidst the 2008 financial crisis.

Less concerned with the risks of navigating between these two poles, Glennie and Bound instead focus on what the appropriate level of autonomy for an agency should be, arguing that this decision should be linked to mission scope and project time horizons. Based on their case study data, they suggest that agencies charged with delivering on longer-term or higher-risk (or more 'radical') remits benefit from greater independence from government intervention, whereas those agencies conceived to handle more focused, shorter-term programmes should have closer relationships with their government sponsors. Indeed, in this latter case, these 'focused' innovation agencies serve as the means, with minimal strategic input, to an end which has been set by policymakers; in contrast, 'radical' agencies have significant discretion to decide on budgets and resource allocation, design R&D programmes, and shape the agency's strategic direction.

The case of Israel's OCS, an agency focused on longer-term, 'radical' innovations, offers an interesting perspective on the issue of autonomy and institutional credibility. Glennie and Bound cite one of the OCS's high-level administrators who asserts that the 'high walls' that existed between the agency and its sponsoring Ministry enabled it to "play a *shaping* rather than an *implementing* role in the development of Israel's innovation strategy" (2016, 31, emphasis added) becoming a powerful locus for innovative activity in that country. However, this administrator does acknowledge that the agency's continued level of autonomy, and indeed authority, was likely the result of the success of many of the OCS's early projects and the 'ethos of success' that emerged around the agency. Somewhat distinct from Haley's (2016, 2017) discussion of the importance of technical expertise and competency as a means of securing institutional credibility, the OCS demonstrates how 'real-world' success can also be an avenue towards this same end, as well as a means of safeguarding continued operational autonomy.

Glennie and Bound also draw a link between how well resourced an innovation agency is and its overall level of autonomy; more independent agencies generally have – or require – greater resources to execute on their greater operational flexibility without having to rely on the involvement or approval of other organisations. In this sense, 'greater' can be taken to simply mean larger budgets and hence the ability to support more projects at a greater level; however, 'greater' can be taken to mean encompassing a wider range of competencies and responsibilities.

Glennie and Bound cite the example of ***CTI,*** a small Swiss innovation agency set-up to provide mentoring and coaching to entrepreneurs and small start-up firms; lacking the staff and resources to perform high-level technology analysis to inform its decision-making process, CTI outsources these functions to "external experts drawn from academia and industry" (Glennie and Bound, 2016, 32). In contrast, the American Defense Advanced Research Projects Agency (DARPA) is able to leverage its massive $3 billion USD budget, and a staff of technical experts drawn from industry, academia, and the military to fulfil its mission of delivering a wide range of scientific, financial, legal, and political support for its projects. Glennie and Bound point to these cases as positive examples, arguing that the resources available to each agency is commensurate with their overall mission and remit.

2.5.3 Methods

- *What kind of support should the agency provide?*
- *What geographic level should the agency work at?*

When considering the kind of support an agency should provide, there needs to be consideration of whether the agency will be focussed on a particular challenge, targeting a specific technology or industry, or will it be more broadly concerned with the entire economy or industrial landscape? In the case of the former, Glennie and Bound point to ***Vinnova,*** a Swedish agency which pioneered the use of 'innovation challenges' as a means of stimulating activity on a targeted technological problem (*ibid.*, 32). In contrast, the Finnish agency ***Tekes*** currently devotes 40% of its operational budget to "reactive funding" for emerging projects that show promise but do not fit into any of its existing support programmes.

The second point raised by Glennie and Bound is the need to consider the developmental stage, or level of technological maturity, of businesses or projects which will be targeted for support. The tools and competencies needed to support early, fundamental research and proof-of-concept work (e.g. R&D grants and assistance with network building) are different from that needed to assist in later-stage prototype scale-

up and commercialisation work (e.g. demand-pull policy instruments or other market-creation measures).

Finally, Glennie and Bound address the question of whether the innovation agency will provide a financial return on the public sector investment being made. The authors note that this question has greater salience for regions, or governments, where public finances are scarce, or where political scrutiny for discretionary spending is particularly high.

On a practical level, a number of financial instruments and support schemes can be implemented, ranging from non-repayable grants to loan guarantees and tax credits or subsidies. There are also more innovative approaches to the funding question: for example, the Israeli agency OCS scales the amount of non-repayable funding it offers to a private sector project based on an evaluation of the size and resources of the firm in question, with start-ups receiving a significantly higher proportion than established companies; royalties are due on these investments only if the project is successfully commercialised. On the other hand, the Finnish agency Tekes exclusively offers low-interest loans to projects that it judges as imminently close to market, on the assumption that these investments are less risky and more likely to be repaid.

However, Glennie and Bound also caution that greater emphasis on financial outcomes can distort the way the agency operates and is evaluated, both internally and externally, in some cases incentivising a shift towards profit-maximizing behaviour and away from its nominal focus on innovation.

Determining the geographic level at which an innovation agency should focus its efforts is directly related to its overall mission, as well as the scale and kinds of resources it can bring to bear, and the kind of support it is designed to offer. In consideration of this point, Glennie and Bound highlight that certain innovation problems, such as major economic or societal issues like climate change, may lend themselves to more centralised, larger-scale solutions and the scope and resources of national (or transnational) governments and policymakers. In contrast, agencies whose mission is to stimulate the growth of a particular industry, or the economic or innovative activity of a specific region, naturally will benefit from a smaller-scale, more localised approach that can be responsive to the local needs and peculiarities.

Glennie and Bound add an additional dimension to the geographic question by noting that with an increasingly globalised supply chain, even regionally-focused innovation initiatives can benefit from “overseas missions” to open up markets and cultivate research collaborations and industrial partnerships; the Taiwanese agency ITRI is a notable success in this regard, with the strategic partnerships it fostered with US technology firms throughout the 1970s and 1980s being credited with accelerating the growth of the former country’s indigenous semiconductor industry.

2.5.4 Metrics

- *What systems and processes should be put in place to understand outcomes?*
- *How can an agency’s overall value be judged?*

The final two questions centre around the need – prior to launch – for a clear understanding of both an innovation agency’s mission, and the means by which that mission will be judged successful. In the latter case, success is often gauged in quantitative terms, using various forms of econometric outputs: increases in employment or patent filings; number of businesses supported or collaborative partnerships formed as a result of agency activities. However, Glennie and Bound (2016) also argue that

more qualitative assessments, usually longer-term in scope, are also valuable metrics by which to judge an agency's impact and overall success. For example, the emergence of a new industrial cluster, or changes in cultural attitudes towards collaboration or the importance of basic R&D activity within the private sector, are both difficult to measure and usually emerge over relatively long time scales, but are valuable outcomes notwithstanding.

While affirming the importance of having well-defined quantitative goals, Glennie and Bound also highlight several ways of accounting for the more qualitative contributions of an innovation agency in an effort to judge its overall value. Foremost amongst these is a consideration of what is distinct about an innovation agency's contribution. For example, the intrinsic value of agencies that provide support to industries or areas for which there is little private sector investment, in contrast to organisations that focus on projects which would have access to resources regardless of public sector intervention.

The authors recommend a more tolerant understanding of project 'failures,' arguing that "since much of what innovation agencies do is experimental, we should expect a high rate of failure, not only in terms of individual projects that are supported, but also in terms of entire programmes" (*ibid.*, 36). The focus could instead be on the speed and decisiveness of an agency's own internal evaluation process: quickly recognising and abandoning unproductive attempts, but also knowing when to scale-up promising initiatives.

3 Different types of innovation agencies

This section focuses more specifically on different types of innovation agencies: the different roles that an agency can play in an overall landscape or ecosystem of different organisations, particularly in terms of its relationship with policy makers and the private sector. The section includes a review of two prominent various classifications devised to categorise these relationships.

3.1 Fixers, builders, drivers and optimisers

3.1.1 Introduction

Glennie and Bound (2016) argue that there is no single model for a successful innovation agency. While their work briefly discusses different kinds of innovation support institutions (technology transfer offices, research funding councils, green investment banks, etc.), their main focus is on the roles that agencies play within the overall 'innovation landscape'. Based on three factors: remit and agenda; institutional structure and capability; and metrics of success, they identify four distinct types: ***Market & System Fixers*****; *Industry Builders*****; *Mission Drivers*****; and *System Optimisers***. They also offer case study examples illustrating the role these agencies can play in their national or regional innovation landscapes.

In outlining their classification, Glennie and Bound warn against a 'copy-and-paste' approach, suggesting that attempts to "directly replicate an organisation that operates in a very different political and economic context and that has a very different mission or a much larger budget are likely to fail" (2016, 6). Nevertheless, they argue that valuable lessons can be learned from international experience of the design and operation of innovation agencies, provided these lessons are viewed in relation to local context.

3.1.2 Market and system fixers

The mission of *Market and System Fixers* (MSF) is to address low levels of private-sector R&D investment spending, and other such innovation market failures. In terms of methods, most support programmes delivered through MSF agencies usually take the form of direct subsidies or grants for both businesses and academic institutions in an effort to catalyse R&D activity. MSF agencies also provide some non-financial support mechanisms, such as assisting with networking and intra-sectoral institution-building activities as a means of bridging systematic gaps.

Support provided by MSF agencies is generally 'technology-agnostic,' aiming to improve the innovative performance of the economy as a whole without preference for a particular industry or sector. This broad focus generally means that as well as its own staff, an MSF agency is reliant on a large external network of experts, drawn from both the public and private sectors, to assist in evaluating projects for funding. An MSF agency must often form strong links with industrial actors, and regularly consult with the private sector on organisational priorities and the most desirable methods of delivering this support. This reliance on outside experts can reduce its autonomy.

Success metrics for an MSF are typically measured in quantitative terms: the value of any intellectual property generated through funded projects; increases in employment or productivity; increases in R&D spending or activity that persist after the conclusion of any intervention. However, there are also several more qualitative metrics that may also be used, such as general attitudes or behaviours towards innovation within an industry or firm, or an increased level of, or even interest in, collaboration between industrial actors that may have arisen.

Of Glennie and Bound's (2016) ten case study examples discussed in their report, three – ***Innovate UK***, Israel's ***OCS***, and ***Tekes*** from Finland – are seen as having MSF-like qualities, particularly in terms of their broad, economy-wide remit and aim to accelerate innovation by developing close relationships with the private sector. Examples of this responsiveness to the needs of the business community include Tekes' extensive use of business consultation exercises to inform its strategy; *ibid*., 58), OCS's practice of using industry consultants as a main means of evaluating technical projects (*ibid*., 64), and Innovate UK's strategy of recruiting technical staff directly from the private sector (*ibid*., 83).

3.1.3 Industry builders

In contrast to the economy-wide remit of an *MSF* agency, *Industry Builders* are organisations focused on accelerating the innovative and industrial activity of a specific technology or sector. Industry builders are typically staffed with scientists, engineers and other subject area experts in order to evaluate and analyse technical and scientific material from their field of interest.

Given the relatively high-level of internal technical expertise, the methods of support offered by Industry Builders range from the more traditional direct financial investments and grants to established companies and academic institutions, to the in-house development and spin-off of new start-up firms. By virtue of their focus on a specific sector, Glennie and Bound also note that Industry Builder agencies often operate in conjunction with industrial cluster support initiatives, by promoting commercialisation and business development activities and the development of indigenous supply chains and "wider support 'ecosystems'" (ibid., 23).

While the desired outcomes for an Industry Builder agency relate to the growth, or emergence, of a particular industrial sector or technology, outcomes of this kind are

typically slow to develop. Over a shorter term, the success metrics for an Industry Builder resemble those of its MSF analogue: increased employment, or the foundation or growth of firms within the sector; number of new patents filed; growth in domestic market share, or increased export activity. Glennie and Bound assert that the Taiwan's ***ITRI*** is a classic example of an Industry Builder-type agency (ibid., 79); The success of that agency's role in the creation and advancement of Taiwan's computer electronics and semiconductor industry relates to its efforts to build up a supporting cluster of suppliers, manufacturers, and research institutes, by identifying and acquiring relevant IP and technical expertise, and funding additional scale-up and development work to ensure integration into the existing Taiwanese industrial landscape.

3.1.4 Mission drivers

While differing in scope, both MSF and Industry Builder agencies are tools used by governments primarily as a means of achieving wider policy goals of economic and industrial transformation: technological developments and innovative activity are being leveraged as drivers of overall economic growth and increased prosperity. In contrast, the aim of a *Mission Driver* agency is to address major social challenges, particularly ones that may lack an overriding economic dimension, such as national defence, healthcare or the environment.

Rather than focusing on incremental improvements or existing technologies, Mission Drivers aim for radical transformations and paradigmatic shifts. Thus, in addition to supporting traditional applied and commercial R&D programmes, Mission Drivers tend to fund more fundamental, basic scientific research than other types of innovation agencies. In practical terms, this support can take the form of direct grants to firms operating in key areas of interest, or leveraging public sector contracts and procurement budgets to provide 'demand pull' support for new and developing technologies. In some cases, highly publicised prize-based challenges or competitions are employed to stimulate interest in developing novel solutions to complex or unusual innovation problems.

In terms of case study examples of Mission Drivers, Glennie and Bound point to the US ***Defense Advanced Research Projects Agency (DARPA)*** (ibid., 88). However, it is interesting to note the distinction here between DARPA, charged with pursuing radical technological breakthroughs in the interest of a major societal challenge (in this case, American military preparedness and national defence) and that of the ITRI, whose mission was the improvement of Taiwan's overall economic performance through the creation of a high technology sector – a somewhat more economically conventional goal, although arguably as radically transformative to that country's industrial output. In contrast, Breznitz and colleagues (2016) categorise both DARPA and the ITRI as 'state-led disrupters' (see below), as this framework places greater importance on the 'driving force' of radical innovative activity, and the links – very close, in both these cases – between agencies and the public sector.

3.1.5 System optimisers

System Optimisers are essentially a modified form of MSF agencies. Whereas MSFs focus on fostering the development of an advanced innovative economy by addressing existing system failures and market gaps, System Optimisers are tasked with ensuring 'continuous global competitiveness' for an existing, largely functional innovation and economic system. Rather than targeting particular industries or technologies, System Optimisers focus on smaller-scale experiments, using new policies and support programmes – the emphasis here is on policy innovation, rather than technological innovation. System Optimisers require deep experience and awareness of how the

public sector operates, and consequently draw a high proportion of its staff from policy analysts, political scientists, and seconded civil servants. However, alongside the need for policymaking nous, system optimisers also rely on industry experts for insights into future technological and market trajectories.

While acknowledging that System Optimisers are less common than other kinds of innovation agencies, Glennie and Bound (2016) point to Israel's ***OCS*** as a representative example. Initially a small agency with minimal resources, the OCS was nevertheless able to introduce a number of experimental policy measures, such as conditional loans whose repayment was contingent on a project's overall market success. The OCS is also credited with a visionary role in establishing partnerships with American and other foreign firms, so building research networks to take advantage of future global technological developments.

3.2 Upgraders, disrupters, facilitators and enablers

3.2.1 Introduction

Breznitz et al. (2018) developed a comprehensive classification of innovation agencies, which while having some overlaps with Glennie and Bound's, places greater emphasis on private sector relationships and the public sector as an instigator of innovative activity. Their framework explores the various ways in which economic and technological development policy goals can be pursued using different kinds of public sector support agencies. They highlight the need for policymakers "to think carefully not only about the tools they use but also the structure of the innovation agencies that wield them" (Breznitz et al., 2018, 883). The authors identify three key contentious issues in innovation agency design:

- *Role in R&D Activity:* Breznitz et al. point to scholars (Mazzucato, 2013; Weiss, 2014) who argue that, in the face of a 'short-sighted or risk-adverse' private sector, the public sector is better positioned to think strategically about the scope and pace of technological development. However, they also note that others (Teubel, 1996; Justman and Teubal, 1995) are critical of state-led attempts to identify relevant R&D problems, arguing that the government role should be merely 'catalytic', enabling the business sector to direct the course of innovative activity.
- *Position in the Public Sector:* According to Breznitz et al., many scholars (Koh, 1997; O'Riain, 2004; Tsui-Auch, 2004) argue that innovation agencies are most effective when they adopt a 'nodal' position, closely linked to government departments and other organisations to foster a high degree of public sector cohesiveness (Chibber, 2002). In contrast, Breznitz and Ornston (2013) highlighted the potential benefits of peripheral agencies which capitalise on a lack of government interference that might reduce their capacity to rapidly respond to changing industrial and technological conditions.
- *Relationship to the Private Sector:* while Breznitz et al. recognise the risk of agency capture by private corporations, others note the benefits of close links with established firms, both as a means of understanding existing industrial and supply chain capacity (Hall, 2001), and in the implementation of initiatives involving technological or industrial transitions (Morris, 2005).

Breznitz et al. (2016) went on to consider the distinct patterns of innovation activity undertaken by agencies. Here, they distinguished between the *nature* of innovation that an agency seeks to pursue (radical or incremental), and the *scope* of activity envisioned (focussed or decentralised). They define radical innovation as "novel breakthroughs, relying on game-changing technologies and new industries to generate enormous wealth and value" and incremental innovation as "a series of small-scale improvements to mature products and

production processes which continue long after the introduction of radical new technologies" (*ibid*., 885). Breznitz et al. refer to incremental innovation as "the unsung heroes of the capitalistic growth miracle" and the best means of securing economic growth (Rosenberg and Birdzell, 1986; Baumol, 2002). In terms of innovation agency scope, Breznitz et al. differentiate focussed innovation as "a relatively narrow set of ambitions objectives or industries" and decentralised innovation, which lacks a distinct technological or industry-specific goal, and instead delegates R&D objectives to a variety of private sector actors.

Breznitz et al. identify four possible combinations of the radical/incremental and focused/decentralised pairs which represent distinct types of successful innovation agencies: *directed upgrader; state-led disrupter; productivity facilitator;* and *transformation enablers*. The authors add that the different types of agencies reflect differences regarding the locus of R&D activity, and relations with the public and private sector (Table 3). Breznitz et al. use case studies to illustrate these types, discussed below.

Table 3: Classification of innovation agencies (adapted from Breznitz et al., 2016)

Type	Nature of Innovation	Scope of Innovation	Locus of R&D Activity	Relationship to Public Sector	Relationship to Private Sector
Directed upgrader	Incremental	Focused	Public	Core	Embedded
State-led disrupter	Radical	Focused	Public	Peripheral	Autonomous
Productivity facilitator	Incremental	Decentralised	Private	Peripheral	Embedded
Transformation enablers	Radical	Decentralised	Private	Peripheral	Autonomous

3.2.2 Directed upgraders

Directed upgraders specialise in incremental innovation but mobilise resources around a relatively narrow range of industries and activities, within which they are deeply embedded (Breznitz et al., 2016, 886). Directed Upgraders are well-integrated into the public sector, with strong links to government ministries and other support organisations. Some Directed Upgraders undertake in-house R&D work as part of an effort to shape the technological development agenda for the private sector.

As an example, Breznitz et al. cite the case of the Chilean agency ***CORFO***. Operating under strong leadership from the central government, this agency focuses its efforts on a limited number of high potential sectors of the economy. Consultations with leading industrial actors in these areas are done as a way of learning from previous market failures, and current technological strengths and weaknesses.

Throughout the 1990s, CORFO played a key role in transforming Chile's fishing industry, advancing the sector away from more traditional practices and towards higher value activities like aquaculture and a focus on the international export market (Perez-Aleman, 2005). Towards this end, the agency established public research institutes, as well as

undertaking its own field studies looking for promising aquaculture sites, and enacting new industry quality standards and regulations to increase Chilean export competitiveness. CORFO also spearheaded collaborative R&D efforts between public and private sector actors to develop vaccines for fish diseases. By 2000, these efforts led to Chile being one of the largest exporters of salmon in the world (*ibid.*).

However, Breznitz and colleagues also point out some criticisms of CORFO, which highlight the limits of Directed Upgraders in general. While the aim of this type of agency is to advance innovative activity in a narrow set of industries or technologies, taken too far this approach can inhibit contributions from outside the field of interest; indeed, by 2016, only 5 of CORFO's 62 initiatives were aimed at new sectors.

The authors assert that "coordination with government agencies, which have their own agendas, and constant contact with existing private sector organizations have meant that CORFO [was] hemmed in" (*ibid*., 890), limited to enacting relatively conservative measures that targeted incumbent industries with established political constituencies. While directed upgraders do have a distinct role to play, overreliance on this type of agency to the exclusion of other policy measures can leave other areas of broader economy underserved.

3.2.3 State-led disrupters

State-led disrupters excel at fostering radically innovative – though narrowly targeted – technological breakthroughs (Breznitz et al., 2016, 890). Their narrow focus, coupled with "formidable in-house technological knowledge" allow state-led disrupters to be both highly effective sources of independent R&D, and being able to commission and manage projects outsourced to public and private sector laboratories and research institutes.

In contrast to directed upgraders, the more speculative nature of the projects they support generally means less risk of capture by established industrial interests, lending considerable autonomy from private sector influence. Similarly, State-led Disrupters are deliberately situated at the periphery of the public sector, often with relatively small budgets which reflect their marginal status. Ideally, this affords freedom to engage in more experimental activities, focusing on "novel technologies, new private sector partners, heterodox policy instruments, and unconventional business models" (*ibid.*).

The Taiwanese ***ITRI***, one of Breznitz's case study examples, was limited to an annual operating budget of $5M USD, in contrast to that nation's "main innovation agency," the Chungshan Institute of Science and Technology, whose size and funding was an order of magnitude greater (*ibid.*). ITRI was formed in the 1970s to support the growth of new technology industries. Within this remit, the agency was given wide latitude to survey the global technology landscape, and to identify what it regarded as the most promising markets and sectors to target. ITRI's most notable achievement has been its role establishing Taiwan's global dominance in the semiconductor market (Mathews and Cho, 2000; Amsden and Chu, 2003).

Reflecting the relative infancy of the country's industrial sector in the 1970s, ITRI agency adopted a 'seed and develop' approach, acquiring the intellectual property rights to already proven technologies from foreign companies, "developing them to the level of prototype products and then diffusing them to industry, either to existing companies or by spinning out the project teams as private companies" (Breznitz et al., 2016, 890-1).

However, indicative of the 'high-risk, high-reward' ethos of state-led disrupters, ITRI has had a number of notable failures. For example, despite numerous costly attempts over

several decades, the agency has made little progress in the development of Taiwanese biotechnology sector (Wong, 2011). Furthermore, some within the country's technology sector lament the fact that the existence of state-led disruptor agencies like ITRI has distorted the innovative potential of the wider Taiwanese economy, with one industry leader noting that "[ITRI] is the only place in Taiwan where real R&D is taking place," which Breznitz et al. assert has had a chilling effect on the birth of new innovative firms outside of that agency's orbit (Breznitz et al., 2016, 890).

While autonomy and arms-length relationships with both the public and private sectors is a hallmark of the operation of state-led disrupters, in the case of ITRI, Breznitz and colleagues argue that this has not precluded catering to the interests of domestic industries. In recent years, the agency has become increasingly involved in research consortia and formal partnerships with private firms, putting more emphasis on "specific industry needs and inputs" as a means of shaping its strategic vision and focus (*ibid.*). Collaboration on a materials science research programme with bicycle manufacturer Giant is cited as one successful example of this kind of public-private partnership (Mathews, 2002; Hsieh, 2015). Breznitz and colleagues note that this trend towards increasing embeddedness parallels the growth in size and sophistication of the Taiwanese technology sector. More generally, an inevitable tendency for successful innovation agencies to become increasingly linked to successful private sector actors may decrease their operational autonomy.

3.2.4 Productivity facilitators

Productivity facilitators introduce small-scale, incremental product and process innovations across a wide range of established industries. This type of agency is deeply embedded within the private sector, enabling them to identify "relevant industrial needs and [develop] practical, relevant solutions to immediate challenges," but also limiting the scope of these efforts to projects congruent with existing markets and business models (Breznitz et al., 2016, 887).

While not a single agency, Breznitz and colleagues describe the group of Danish ***GTS institutes*** as "an almost ideal" example of this type. Situated at the periphery of the public sector, from which they receive only 10% of their funding, these agencies are described as essentially commercial entities providing, in effect, short-term consultancy services to a range of private sector clients. Despite being a widespread fixture within Danish industry, with nearly 60% of medium and large sized firms working with a GTS institute, these agencies account for a mere 2% of overall R&D spending in Denmark (*ibid.*).

However, the short-term, low-budget nature of GTS projects is presented by Breznitz et al. as a positive, by encouraging "the institutes to apply existing technologies in pragmatic and effective ways" rather than focussing on more ambitious, longer-term programmes (*ibid.*). Towards this end, one of the GTS institutes' most notable achievements was the "network initiative" of the 1990s (Amin and Thomas, 1996; Ornston, 2012), which is cited as key means of enhancing technological diffusion thought the Danish economy, enabling firms to make incremental advances across a range of technology industries through exchanges of knowledge, expertise, and sectoral best practices (Breznitz, 2016, 887-8).

According to Breznitz et al., the main downside to Productivity facilitators is the inherently broad-based, shallow nature of the innovative activity that they foster. The authors, citing Ornston (2012), argue that one of the main weaknesses of the Danish approach is the lack of significant levels of "sustained, focused, and large-scale

industrial policies", with too much being left to the incremental, 'short-termist' contributions of the GTS institutes (Breznitz, 2016, 888).

3.2.5 Transformation enablers

Transformation enablers are in many ways similar to p*roductivity facilitators*: both operate at the periphery of the public sector with a limited budget and resources, and minimal government input. Breznitz cites the example of ***Sitra****,* a Finnish innovation agency nominally overseen by the Bank of Finland, but with a budget "so diminutive that it was effectively ignored by the bank and other civil servants," which according to a former Finnish policymaker "enabled the agency to experiment with unorthodox policy instruments with little political interference" (Breznitz et al., 2016, 892).

In contrast to the more practical, incremental focus that engendered close relationships between Productivity Facilitators and well-established private sector actors, Transformation enablers such as Sitra are limited to collaborations with "firms at the periphery of the Finnish innovation system, in industries such as electronics that were ignored or even maligned by industrialists at the time" (Breznitz and Ornston, 2013). The authors frame this marginal status as central to Sitra's approach to innovation support: rather than focusing on large-scale, resource intensive projects in a small number of key sectors, Sitra instead focused on supporting more speculative, radical innovations across the entire Finnish industrial landscape. One of the first organisations in Finland to offer non-repayable R&D grants, and a pioneer in brokering venture capital partnerships, Breznitz and Ornston credit Sitra with helping shift the Finnish economy away from a reliance on resource extraction, and low-skill assembly and mass production work, into one of the most innovative countries in the OECD (*ibid*., 1227-1228).

However, the marginal, resource-poor status of transformation enablers such as Sitra also present significant weaknesses. Breznitz and Ornston (*ibid.*) note that while Sitra was responsible for introducing several new innovative policy instruments – venture capital funding models, for example – it was forced to rely on larger agencies and government departments such as ***Tekes***, the 'flagship' Finnish Funding Agency for Innovation, to capitalise on these successes, or indeed fund programmes beyond an initial 'proof of concept' phase. Similarly, a lack of clout or allies within either the public or private sectors meant that Sitra had little sway with influential stakeholders, relying instead on economic or political crises in order for their 'heterodox strategies' to gain traction in mainstream policy discussions (*ibid.*).

Similar to the case of ITRI, a peripheral s*tate-led disrupter* whose successes led to greater industry embeddedness, Sitra's early achievements have resulted in increased political scrutiny and oversight. Formally brought under the purview of Finnish parliament in the late 1990s, Breznitz and colleagues (2016, 893) argue that the current agency has transitioned into the role of a directed upgrader, with greater resources and links to the public sector coming at the expense of its formerly radical nature.

4 Specific functions of innovation agencies

4.1 Introduction

Focusing less on broad categories of innovation agency types, there is a body of academic literature that addresses the specific activities (or functions) they perform. One

of the key empirical findings from these detailed studies is the level of specialisation and division of labour between the innovation agencies operating within the same industry or region, with different organisations suited to providing different kinds of support.

Recent work in this area has been strongly influenced by Howells (2006), who provided a comprehensive outline of the various activities and functions of 'innovation intermediaries' which he defined as:

> An organisation or body that acts as an agent or broker in any aspect of the innovation process between two or more parties […] helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator, or go-between, bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations (Howells, 2006, 720)

Although Howells' case study work focusses on the activities of private sector intermediaries, such as consultancies, trade groups, and brokerage companies, subsequent studies have extended his framework to public sector agencies and government institutions (Kivimaa, 2014; Kanda et al., 2018).

Based on the review and synthesis of a host of previously published studies and academic works, as well as his own case study analysis, Howells (2006) identified 10 functions untaken by innovation intermediaries (Table 4).

Table 4: Functions of innovation intermediaries (based on Howells, 2006)

Function	Description
1) Foresight and diagnostics	Includes technology forecasting, as well as providing advice on the changing regulatory and policy landscape
2) Scanning and information processing	Identifying and vetting potential collaborators and partners
3) Knowledge processing and combination/recombination	Comprises both the in-house generation of technical knowledge, as well as assisting in the exchange and combination of knowledge between partners
4) Gatekeeping and brokering	Assisting with partnership or collaboration formation, including formal contract and deal negotiations
5) Testing, validation, and training	Providing testing and laboratory facilities, assisting with scale-up and prototypes, and developing training programmes
6) Accreditation and standards	Offering advice on standards development, and in some cases serving as formal accreditation and verification bodies
7) Regulation and arbitration	Functioning as an "independent and impartial" enforcer of industry regulations and best practices
8) Intellectual property management	Assisting clients with securing and enforcing IP rights protection
9) Commercialisation	Providing market research and business planning; assisting with securing early-stage funding, and negotiating with venture capital firms
10) Evaluation of outcomes	Assessing the performance of products and technology within the marketplace (feeding back into functions 1 & 9)

Howell (2006) notes that there are a host of UK private sector innovation intermediaries performing there functions of activities. Indeed, one of the more noteworthy insights to arise from his work was the realisation that innovation intermediaries undertook considerably more functions than previous scholarship had presumed, including a number of "unrecognised or undervalued roles" such as technology foresighting, IP management assistance, and a range of accreditation, regulation, and standards work (ibid., 721).

Later studies on innovation intermediaries have been greatly influence by Howell's seminal work. Rather than private sector agencies, several subsequent studies (e.g.

Bessant and Rush, 1995; Klerkx and Leeuwis, 2009; Hakkarainen and Hyysalo, 2016; Mignon and Kanda, 2018) have focussed on the functions and activities of public sector or government-affiliated innovation agencies and intermediaries, and the role they play in accelerating technological innovation. The rest of this section considers two such studies, by Kivimaa (2014) and Kanda and colleagues (2018), chosen because of their focus on renewable energy and climate change policy initiatives in northern European countries, and their resonance with the current Scottish policy landscape.

4.2 Innovation agencies in North Rhine Westphalia and Scania

Kanda et al. (2018) look at a variety of innovation agencies and intermediaries at work within two regions – the German state of **North Rhine Westphalia**, and the **Scania** region of Sweden – and how they support 'eco-innovation'[2] initiatives. The various functions of these agencies are divided into eight categories, using modified version of Howells' (2006) ten functions for private sector innovation intermediaries (Table 4).[3] Kanda et al. stress that their set of eight functions is not intended to be exhaustive, and that the omission of any particular function (compared to Howells, for example) is more a reflection of its absence in their case study data than a normative judgement as to the relative importance of these activities.

Table 5 summarises Kanda et al.'s (2018) analysis of the innovation agencies at work in the North Rhine Westphalia region, showing the various support functions provided by five public sector innovation agencies or intermediaries (the Greentech Cluster; the Efficiency Agency; the Energy Agency; Agency for Business Promotions; Essen Economic Development Agency) within the eight categories.

[2] According to Kanda et al. (2018), eco-innovation is "the development and/or adoption of innovations that improve environmental performance of production and consumption activities from a lifecycle perspective, with or without prior intention".

[3] For example, the "Evaluation of Outcomes" function is absent in Kanda et al.'s framework, as is any explicit mention of intellectual property management (functions 10 and 8, respectively, in Howells' work). Similarly, there is more emphasis on providing access to financial and technical resources in Kanda et al.'s framework (functions 4 – 6), and while ensuring compliance with government regulations and policies is briefly mentioned as an aspect of branding and legitimation (function 8), there is less overall emphasis placed on developing or monitoring industry standards and accreditations. These differences may reflect Kanda et al.'s focus on eco-innovation which the authors, writing in 2018, frame as a relatively nascent branch of innovative activity, with the majority of the target 'client firms' still focused on securing funding, or early-stage R&D and technical matters, and consequently less concerned with still-evolving regulatory or IP management issues.

Table 5: Innovation support functions provided by agencies in North Rhine Westphalia (adapted from Kanda et al. 2018)

Function	Examples	Greentech Cluster	Efficiency Agency	Energy Agency	Agency for Business Promotions	Essen Economic Dev. Ag.
1. Forecasting and roadmapping	• "Innovation radar"- an annual list of cutting-edge eco-innovations for firms	•				
2. Information gathering and dissemination	• Providing arenas for meeting and information sharing • Gathering and distributing information among key stakeholders	•	•	•	•	•
3. Fostering networking and partnerships	• Providing arenas for meetings • Facilitating collaborations between key stakeholders	•	•	•	•	•
4. Prototyping and piloting	*[not present in this case study locale]*					
5. Technical consulting	• Technical expertise on energy and material • efficiency, and their related project implementation		•	•		
6. Resource mobilisation	• Assistance with financing applications • Information on sources of finance and human capital		•		•	•
7. Commercialisation	• Assistance with market entry • Export promotion services			•		
8. Branding and legitimation	• Fostering social acceptance and compliance with eco-innovation technologies and initiatives	•	•	•	•	•

While there is significant overlap between the various agencies in the delivery of some functions – for example, *information gathering and dissemination* (function 2), *fostering networking and partnerships* (function 3), and *branding and legitimation* (function 8) – there are several functions that are addressed by only one or two organisations. For example, the Greentech Cluster was the only agency that provided significant support for *forecasting and roadmapping* (function 1), while only The Energy Agency provided assistance with *commercialisation* (function 7).

One of the key findings in Kanda et al.'s study is the tension between specificity and breadth in terms of an innovation agency's scope and mission. Based on their empirical work, they conclude:

> The scope and different type of intermediation roles suggests that different characteristics of intermediaries (e.g. their resources, mandate, motivation, scope) influences their intermediation roles and that not all intermediaries can be expected to perform certain roles (Kanda et al., 2018, 1014)

In the case of North Rhine Westphalia, Kanda and colleagues note the diversity of the innovation agencies in this region in terms of "type of organisation, size, source of funding, and how long they had been active" (ibid., 1010), and argue that resource limitations – particularly in terms of staff, financing, and technical resources – are a major determinant in the scope and range of support activities offered by a given agency. For example, the Greentech Cluster was a relatively new addition to the innovation landscape, founded in 2009 and operating with a staff of 5-6, compared to the other organisations which had all been in operation for between 20 and 40 years, with staff levels of at least several dozen (rising to over 120 in the case of the Energy Agency).

Additionally, Kanda et al. note how the relatively small Greentech Cluster was not designed to engage in more resource-intensive activities like *prototyping and piloting* (function 4) or *technical consulting* (function 5) – or how long-standing agencies with greater resources and deeper connections to North Rhine Westphalia's economic and industrial landscape would be better positioned to offer aid with *resource mobilisation* (function 7) or *commercialisation assistance* (function 8).

In addition to their case study observations regarding the division of responsibilities amongst innovation agencies in a given region, Kanda and colleagues offer some observations about what they consider to be the specific characteristics of eco-innovation, and how the roles of intermediaries in eco-innovation differ from the roles of intermediaries in 'conventional innovation' (ibid., 1013).

Here, they argue that networking and knowledge exchange efforts – *information gathering and dissemination* (function 2) and *fostering networking and partnerships* (function 3) – are especially important, due to the complexity and systematic nature of eco-innovations, which often require "changes in raw materials or components, logistical and technical integration with a range of partners, and re-design of products and services" (*ibid*., 1013). Furthermore, they assert that due to the inherent novelty and transformative nature of eco-innovations, particular attention must be paid to branding and legitimation activities (function 8). This ensures that "the environmental benefits of these innovations can be measured, validated and also made visible to key stakeholders such as the general public and policy makers". They see these as necessary preconditions for the development of the political will to enact policy changes, and the growth of market demand from consumers. Notably, each of the five case study innovation agencies are reported as delivering all three of these functions.

4.3 Innovation intermediaries in Finland

Kivimaa's (2014) analysis of government-affiliated innovation intermediaries in Finland builds on analytical frameworks initiated by scholars such as Bessant and Rush (1995) and Howells (2006) Similar to Kanda et al.'s (2018) work, Kivimaa describes the distinct, though complimentary roles of two Finnish technology innovation agencies: Sitra and Motiva. In addition, Kivimaa also highlights some important points on issues of technological neutrality and agency autonomy, and the impact this can have on the delivery of ambitious – and urgent – socio-technological, economic, and industrial transitions towards carbon neutrality.

As discussed in some detail above, Breznitz and colleagues described the role of Sitra in the first decades after its founding as a somewhat marginal, resource poor *Transformation Enabler*, operating with significant autonomy from both the private and public sectors and targeting radical technological developments across the breadth of

the Finnish economy. However, Breznitz et al. also noted that by the late 1990s the agency's success led to both an increase in linkages with Finnish industry, as well as an increasingly nodal position within the public sector, alongside increased access to financial and technical resources.

Kivimaa's description of Sitra's operations in the 2010s accords with Breznitz et al.'s assertion that the agency was transitioning away from more radically-focussed, peripheral role. Indeed, Kivimaa presents Sitra as a prominent figure in the Finnish innovation landscape, using its significant financial resources and staff of over 100 employees to "promote sustainable well-being in Finland" by support technological innovation across a range of technologies and industrial sectors (ibid., 1373). As a consequence of its broad brief, Sitra's support programmes tend to be relatively short-lived; Kivimaa notes that "its energy related tasks were done on a temporary basis through an energy programme [run] between 2008 and 2012" (*ibid.*).

In contrast to larger and more broadly-focussed SItra, Motiva is described by Kivimaa as "an expert company" owned by the Finnish government and dedicated exclusively to promoting efficient and sustainable energy use, serving as a "critical energy intermediary and a key implementer of energy efficiency policy in Finland" (Kivimaa, 2014, 1373; Hodson et al., 2009). Motiva's comparatively small staff of 57 works closely with local governments, as well as businesses, communities, and consumers, to support a range of energy efficiency projects.

While Kivimaa's (2014) analytical framework is similar to Howells (2006), she adds an additional level of refinement by grouping an exhaustive list (+20) of functions and activities under three broad categories: *Articulation of expectations and visions, Building of social networks,* and *Learning processes and exploration at multiple dimensions,* as well as a fourth general category *'Other'.* Examples of each of these categories are shown below in Table 6, alongside a summary of the empirical evidence on the extent (strong, medium, weak, or absent) to which each agency provided a particular support function or activity.

Table 6: Innovation Support Functions Provided by Sitra and Motiva (adapted from Kivimaa, 2014)

Function	Examples	Evidence of provision of function by agency	
		Sitra	Motiva
Articulation of expectations and visions	articulation of needs and requirements	Strong	Medium
	strategy development and foresighting	Medium	Absent
Building of social networks	building networks and brokering	Medium	Strong
	configuring and aligning stakeholder interests	Strong	Medium
	securing funding and financial resources	Strong	Weak
Learning processes and exploration at multiple dimensions	knowledge generation, gathering, and dissemination	Strong	Strong
	training, technical advice, and support	Medium	Strong
	funding for prototyping and pilot projects	Strong	Absent
'Other'	Long-term project design and management	Weak	Medium
	Policy implementation	Absent	Strong

Kivimaa (2016) argues that these empirical findings present two clearly different types of government-affiliated agencies. Sitra, with its wider 'system-level' focus and greater resources, excels at assisting with strategic planning and forecasting, as well as drawing on a large network of public and private sector actors to provide material and financial support for innovation programmes. In contrast, by virtue of its narrow, and longer-lived, focus on a specific area of technological innovation, Motiva is able to offer a high level of technical knowledge and expertise, as well as engaging more deeply in the practical elements of policy implementation and technological development. Despite these differences, it is interesting to note that both agencies were highly involved in networking activities between stakeholders, as well as heavily invested in knowledge gathering and exchange activities.

While asserting that Motiva and Sitra have "rather complimentary roles with each other in the sustainability advancement of the Finnish energy regime" Kivimaa also notes the challenges each agency faced regarding the notion of 'technological neutrality', as a

result of their divergent roles (note that this echoes similar issues with autonomy raised in Section 3). For example, as of 2014, neither Motiva nor Sitra had expressed a preference regarding the 'technological battle' over renewable energy heating options – electric heat pumps versus wood or other biofuels, etc. – eschewing advocacy or legitimation activities and instead opting to focus on "provid[ing] information and user experience" data (ibid., 1378).

In the case of Motiva, Kivimaa argues that its strong links to dominant stakeholders in the existing Finnish energy landscape, including both industrial firms as well as policymakers and other government stakeholders, although arguably one of its greatest strengths, also inhibited the agency's ability to disrupt the existing energy system and favour one kind of renewable heat technology over another. For Kivimaa, this "indicat[ed] a degree of lock-in to the existing regime" (2016, 1378). Conversely, Sitra's standing as a 'temporary transitional actor' and its relatively short-lived involvement in the renewable heat sector meant that it possessed neither the technical expertise nor the institutional authority to credibly influence the issue. Kivimaa sees this as a fundamental weakness in the Finnish renewable energy system, and the agencies put in place to support technological innovation, arguing that:

> avoiding the 'technological battle' may be possible when time and resources are abundant, [but] the urgency of climate action, financial crises, and extending scales from technologies to systems may well mean that more 'directed' transition intermediaries are needed (Kivimaa, 2014, 1378).

In making this observation – nearly a decade ago – Kivimaa appears to anticipate the current policy shift surrounding the need for urgent action on decarbonisation and the climate crisis, adding weight to the argument in favour of the need for directed interventions, which may include decisions over 'technological battles' in order to deliver decisive action.

5 Discussion and policy implications

There are several broad conclusions and policy implications that arise from the research literature reviewed here, spanning both multiple analytical frameworks and case study examples.

5.1 Classifications and contexts

The report introduced a number of detailed classifications and means of categorising innovation agencies, in terms of different *designs, types* and *functions* of innovation agencies as well as the particular roles they can play in a national or regional innovation system. While these frameworks offer useful insight, it is important to emphasise the limits of an overly generalised understanding of the role of innovation agencies. Differences in local conditions, including the particular industrial, economic and technological capacities of a given region may make it difficult to fit a given agency into a suggested classification. This is particularly salient in terms of drawing comparisons between historical or international examples which may diverge from the current policy or economic context in significant ways.

In this regard, the work of Haley and Watson (Section 2) are particularly useful, in that they provide a range of points to be considered in the design and conception of an innovation agency, charging policymakers and other stakeholders to tailor the scope, mission and other attributes of such an organisation to best fit local conditions.

Alongside the discussion of the role and purpose of any one particular agency, the case study examples in this report – especially those from Kivimaa and Kanda et al. (Section 4) – emphasise that a robust innovation system invariably features multiple agencies and support organisations working in concert, each focusing on its own area of expertise and according to its mission and remit. This calls attention to the importance of strong networks and working relationships between innovation agencies, as well as the need for robust means of knowledge exchange and dissemination to ensure that actors and stakeholders can carry out their mission in concert with one another.

This report has also highlighted how the role of a specific innovation agency can shift over time – for example, the Finnish case of Sitra – as both public policy priorities and/or the needs of the private sector develop and evolve. This emphasises the need for continual attention to be paid to the role and efficacy of a given agency or support initiative, to ensure that it remains aligned with and attentive to the needs and goals of the current innovation system.

5.2 Tensions between autonomy and embeddedness

Arguably one of the more persistent and significant issues that arose across multiple frameworks and case studies is the tension between innovation agency autonomy and its embeddedness in the public or private sectors. These elements were a central feature in Breznitz et al.'s framing of the role of an innovation agency, and were linked to the nature of innovation – radical or incremental – that an organisation could support, as well its overall, system-wide impact. Broadly speaking, the suggestion here is that the stronger the linkages are between an agency and the existing political or industrial paradigm, the less likely that agency is to support radical innovations that may be disruptive to the existing system.

Watson's work on the ETI case study raises similar points about the risks of having leading entrenched industrial actors play such a strong role in the leadership and operation of an innovation agency. However, it is important to note that pressures on autonomy can come from the public, as well as the private sectors. This point is made in the work by Kivimaa, who argued that in the Finnish context, the well-embedded agency Mitra was reluctant to advocate for technologies that might disrupt the existing energy system, due to its close relationships with entrenched actors from both industry and government.

These points are arguably of particular salience to the contemporary Scottish policy landscape, where the environmental externalities of climate change, and the need for urgent action to achieve carbon neutrality have been internalised at a high level. Kanda et al. address this point directly, pointing to the inherent risks of a public sector response that, in a desire to achieve ambitious, time-sensitive policy goals, is overly reactive to the expressed needs of private industry.

Perhaps inevitably, given the urgent pace of change required, current priorities on heat decarbonisation have prioritised commercial or near-commercial technologies such as electric heat pumps and networks over less developed options such as green hydrogen. Even so, the broader point remains salient: designing an effective innovation agency in this context requires that short-term targets and needs are balanced against longer-term opportunities and strategies.

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