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Challenging the "deficit model" of innovation: Framing policy issues under the innovation imperative

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ABSTRACT

As innovation is increasingly becoming an imperative for policymakers around the globe, there is a growing tendency to frame policy problems as problems of innovation. This logic suggests that we are unable to address grand societal challenges and ensure economic competitiveness *because* our societies, institutions, scientific activities or individual predispositions are not sufficiently geared towards innovation. In this paper, we analyze this "deficit model" of innovation in which a lack of innovation is routinely invoked as the main obstacle to social progress. Drawing parallels to research on the deficit model of public understanding of science (PUS), we develop a theoretical framework that captures the dynamics and normative implications of deficit construction, highlighting five salient dimensions: problem diagnoses, proposed remedies, the role of expertise, implied social orders, and measures of success. We apply this framework to three empirical case studies of recent innovation strategies in Luxembourg, Singapore, and Denmark. Attention to this deficit framing around innovation is important, we argue, because it is an essential part of how innovation transforms societies in the 21st century: not only through new technological possibilities or economic growth, but also by shaping public discourse, narrowing policy options, and legitimizing major institutional interventions. The implied pro-innovation bias tends to marginalize other rationales, values, and social functions that do not explicitly support innovation. It further delegates decisions about sweeping social reconfigurations to innovation experts, which raises questions of accountability and democratic governance. Experiences from the history of PUS suggest that, without a dedicated effort to transform innovation policy into a more democratic, inclusive, and explicitly political field, the present deficit logic and its technocratic overtones risks significant social and political conflict.

1. Making public policy in an innovation era

Innovation has become a leitmotif of policy making and institutional design (Pfotenhauer & Jasanoff 2017a). The European Commission instructively labeled the continent an "Innovation Union," setting the tone for European self-imagination in the new millennium (EC, 2011). Across the globe, ministries and agencies of innovation are being created or carved out of existing government portfolios, churning out countless strategies and reports. Universities – in the past, often portrayed as ivory towers of open-ended tinkering with ideas – have found their 21st-century mission primarily as "innovation engines" (Mansfield and Lee, 1996; Mowery, 2004; Thorp and Goldstein, 2010; Pfotenhauer, forthcoming) with significant consequences for their internal organization, funding models and assessment. Geeks and tech entrepreneurs have moved out of the countercultural margins of society and into the public and economic mainstream, frequently serving as role models for today's teenage generation. Fittingly, the topic of this special issue in *Research Policy* highlights the transformative power of innovation.

With growing ubiquity, the call for innovation is increasingly taking the form of an "innovation imperative" across countries and sectors. The Organisation for Economic Co-operation and Development notes in its "Innovation Strategy" that "while no single policy instrument holds all the answers, innovation is the key ingredient of any effort to improve people's quality of life. It is […] essential for addressing some of society's most pressing issues, such as climate change, health and poverty" (OECD, 2010). The European Commission has diagnosed an "Innovation Emergency [whereby] Europe is spending 0.8% of GDP less than the US and 1.5% less than Japan every year on Research & Development (R&D). Thousands of our best researchers and innovators

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have moved to countries where conditions are more favourable" (EC, 2016). In its 2011 Strategy for American Innovation, the Obama White House likewise proclaimed that "America's future economic growth and international competitiveness depend on our capacity to innovate. […] To win the future, we must out-innovate, out-educate, and out-build the rest of the world" (The White House, 2011).

This "innovation imperative" has changed something about the way we bring the concept of innovation to bear in public policy: formerly principally an analytic category used to explain technological change and economic growth, innovation has become a framing device – a kind of diagnostic lens – through which we tend to frame policy problems as problems of innovation. The call for more innovation has become a panacea policy response that promises to solve problems almost independently of their specifics (Pfotenhauer and Jasanoff, 2017a). Complex social challenges that, a decade ago, might have been framed differently – from low literacy rates to sluggish economic growth, growing inequality, obesity, traffic congestion, environmental degradation, all the way to climate change – now all demand innovation-centered solutions. Conversely, this logic suggests that we are unable to address our grand challenges or ensure economic competitiveness *because* our societies, institutions, scientific activities or individual predispositions are not sufficiently geared toward innovation. The innovation imperative is further exacerbated by perceived international competition pressure and the threat of falling behind, as illustrated by the above quotes from the European Commission and the White House Strategy.

In this paper, we analyze this emerging pattern whereby policy problems are framed as problems of innovation and where a lack of innovation is routinely invoked as the main obstacle to social progress. We call this pattern the "deficit model of innovation" (DMI) because of salient parallels to the so-called deficit model of public understanding of science (PUS), which we will discuss below. Under this deficit model, innovation is increasingly wielded as a political framing device that constructs parts of society and various social institutions as insufficient and in need of an innovation agenda.[1] We argue that closer attention to this deficit framing is needed because it is an essential part of how innovation transforms societies in the 21st century: not only through new technological possibilities or economic growth, but also by structuring policy options and acting as a source of legitimacy with profound consequences for how we envisage and justify social change. Diagnosing innovation deficits, we argue, is a political act that prevents alternative (and perhaps more appropriate) policy framings.

Harnessing the transformative power of innovation and directing it toward the public good will thus require an explicit shift from "innovation policy" to "innovation politics," supported by new forms for democratic deliberation. This puts our paper in direct conversation with what Schot and Steinmueller (2016) call an emergent "Frame 3" for innovation policy aimed at directed "transformative change." In our opinion, the development of better policy instruments cannot proceed disconnected from thorough political discussions about the means and ends of innovation policy – i.e. which futures we collectively want, and how we want to get there. Here, innovation policy has much to learn from previous science policy debates around PUS, as discussed below. Our paper thus adds to the growing body of research that emphasizes the need for reflexive and critical engagement with innovation, as witnessed by the emergence of the responsible innovation paradigm (Stilgoe et al., 2013; von Schomberg, 2013) and growing calls for a more reflexive stance toward innovation systems approaches (Kuhlmann et al., 2012).

In the following, we first develop an analytic framework for how the deficit logic operates, drawing on scholarship on PUS. We then apply the framework to three case studies to demonstrate its analytic purchase in analyzing recent innovation strategies in Luxembourg, Singapore, and Denmark. We conclude by outlining the implications of our research agenda for innovation scholarship and public policy.

2. Analyzing deficit frames – a theoretical exploration

In this section, we develop an analytic framework to capture the dynamics and normative implications of the widespread deficit logic in innovation policy. We draw parallels to previous critical scholarship on the public understanding of science and technology (PUS) that also uses the notion of a "deficit model" as both an analytic lens and a critical intervention. In particular, we identify five dimensions that make it possible to systematize the various layers of deficit construction: (1) the kind of deficit that is being diagnosed, (2) the remedies proposed to address this deficit, (3) the forms of expertise considered legitimate in addressing the deficits, (4) the social orders implied by, or coproduced with, the proposed technoscientific solution, and (5) the standards of success and the corollary normative implications of the intervention. Note that the term "deficit model" is an analytic category that is not proactively used by scientists or by policymakers. Rather, it is an analytical concept employed by social scientists to identify, critique, and intervene in traditional policy responses to public controversies surrounding science and technology.

2.1. The deficit model of public understanding of science and technology (DMS)

In scholarly work on PUS, the term "deficit model" (henceforth DMS) refers to how scientists, policymakers, and other elites tend to frame negative public responses to scientific claims and technological developments in terms of *deficiencies* on the part of the public (e.g., misunderstanding or hostility to progress). While there is no clear-cut definition of the DMS in the literature, its origins are usually traced to a 1985 Royal Society report ("Bodmer Report"), which explored public attitudes, understanding, and use of scientific knowledge (Royal Society, 1985). The Bodmer Report provided a fresh look at public controversies surrounding science and technology. In the words of one of the authors, a "simple deficit model, which tries to interpret the situation solely in terms of public ignorance or scientific illiteracy" had failed to provide adequate explanations and effective mitigation strategies for science controversies or "anti-scientific attitudes" (Ziman, 1991).

Countering this deficit model, Ziman and others argued that science is not a well-bounded activity and that scientists, too, do not draw on one coherent, unitary scientific framework for making decisions. Rather, both scientists and lay people make sense of the world in fragmented, inconsistent and inevitably socially mediated ways (Ziman, 1991). Wynne (1992), in his groundbreaking study on the "misunderstood misunderstandings" of lay responses to expert intervention in post-Chernobyl northern England, observed that

> experiences of risks, risk communications or any other scientific information is never, and can never be, a purely intellectual process, about reception of knowledge per se. People experience these in the form of material social relationships, interactions and interests, and thus they logically define and judge the risk, the risk information, or the scientific knowledge as part and parcel of that "social package." (p. 281)

Hence, the ascription of a deficit rather stems "from a broad anxiety among scientists and policy makers about what they see as the public's inability or unwillingness to understand 'correct' messages about risks as given to them by the experts" (Wynne, 1992). Moreover, "The Public" is commonly taken to be an undifferentiated, ignorant mass that stands opposed to an (often equally monolithic) "Science" (see, e.g.,

[1] This deficit framing resonates with Evgeny Morozov's notion of solutionism (Morozov, 2013). However, in contrast to Morozov, our analysis focuses primarily on the level of public policy, not specific technologies or Silicon Valley companies.

Michael, 2009). This monolithic view fails to account for internal diversity and possible controversy within science. It also fails to recognize that equally rational people can disagree about the meaning and desirability of any given scientific or technological advancement on normative grounds. According to Wynne, the DMS fails to recognize that "many public concerns relate to the science […] but are not scientific issues" (Wynne, 2007).

These insights explain why traditional *remedies* proposed to reduce the "deficit" have rarely had the desired effect. If the diagnosed problem were indeed one of insufficient scientific understanding or irrational fear, then initiatives in science literacy and science communication would guarantee more favourable attitudes toward science and lead to a convergence of public and expert opinion. However, decades' worth of PUS research has shown that such initiatives are marginally effective at best and more likely harmful to creating a more robust and symmetric relationship between science and society. According to Wynne, the focus on scientific literacy is based on the "false assumption that public concerns are only about instrumental consequences, and not also crucially about what human purposes are driving science and innovation in the first place" (Wynne, 2005).

Some Science and Technology Studies (STS) researchers have argued that "deficits" are symptomatic of deeper underlying institutional pathologies (Wynne, 2006) and an unavoidable "overflowing" of institutionally pre-configured science–society interactions (Callon et al., 2009). Questions such as Why this technology? Why not another? Who needs it? Who is controlling it? Who benefits from it? Can they be trusted? What will it mean for me and my family? Will it improve the environment? What will it mean for people in the developing world?" are central to discussions about technoscientific progress (Wilsdon and Willis, 2004). Stirling argues that the focus, in (critiques of) public engagement in technoscientific controversies, on why they have been implemented – i.e. for substantive, normative or instrumental reasons – or whether they arrived at more broadly supported decisions is partly misleading. Instead, greater attention should be paid to whether these processes enable the "opening up" of governance commitments and may hence provide pathways to alternative forms of governance in technoscientific projects (Stirling, 2008). More generally, STS scholarship has argued for "a move from deficit to dialogue" and that greater openness and more participation (e.g., in the form of public engagement) can lead to substantively better decisions and more democratically legitimate processes (Irwin, 2014; Stilgoe et al., 2014).

At the heart of the DMS is an institutional commitment – or "neurosis," as Wynne calls it – on the part of science to safeguard its credibility and authority by demarcating its own *"expert" knowledge* from "lay" knowledge. Under a deficit framework, scientific knowledge is superior to lay knowledge because it adheres to higher epistemological standards guaranteed by the scientific method (Collins and Evans, 2007; Jasanoff, 1987). As a result, experts should be granted a principal role in the policy process, frequently trumping popular judgment (Jasanoff, 1994). Lay disagreement with authoritative expert prescriptions, in this sense, is seen as a mere expression of "unruly publics" (Saille, 2015; Wynne, 1988). In practice, this epistemic hierarchy has proven hard to maintain and highly problematic on democratic grounds (Jasanoff, 2005a).

The knowledge hierarchy implied by the DMS and the authority it grants to experts has profound consequences for *public policy*. Jasanoff (2005b) has argued that the DMS "can be seen in effect as a kind of tacit democratic theory – a theory that presumes ignorant publics in need of rescue by the state and grants science a privileged place in forming, and informing, an educated citizenry." Frequently, it is driven by unwarranted technological optimism and hubris among scientific and policy elites (Jasanoff, 2003; Tiles and Oberdiek, 1995). Proponents of the DMS sometimes see "ignorant publics" as unfit for democratic participation because they lack sufficient knowledge about the very issues they are deciding upon (Bauer et al., 2007). This rings particularly true in an era where "post-truth" has become a common way to dismiss populist politics.

The hierarchization between different types of knowledge put forward by the DMS is thus not solely an epistemic proposition; it is deeply normative. Scientific illiteracy is viewed as a moral deficit: "Given the centrality of science and technology to the modern world," Sismondo suggests, "scientific illiteracy is viewed as a moral problem, leaving people incapable of understanding the world around them and incapable of acting rationally in that world" (Sismondo, 2003). Attempts to "put science in its rightful place," as Obama proclaimed in his second inaugural address, are thus at once assertions of expert authority over public dissent and "colonizations of public meanings" in controversial social and political areas in predominantly scientific terms (Wynne, 2015). By limiting public responses to public technoscientific controversies to scientifically approved positions, participation "never gets to address what research questions come to be seen as salient, with what imaginations of human ends and possible outcomes" (Wynne, 2007). The *success* of any interventions in public controversies on science and technology in the DMS is thus entirely determined by widespread acceptance of scientific rationality, presumably rooted in a sufficient level of public science literacy.

2.2. Toward a deficit model of innovation (DMI)

To interrogate the dynamics of a parallel "deficit model of innovation" (DMI), it seems best to take the scholarly investigations into the DMS as a guideline. The starting point is again the question: What kind of deficit is being diagnosed? As has been argued above, the DMI logic intimates that societies are unable to address grand societal challenges or ensure economic competitiveness because their policies, institutions, scientific activities, or individual predispositions are not sufficiently oriented toward innovation – in short, because of a *lack of innovation*. This lack is usually expressed in terms of innovation capacity, whether at the national, regional, organizational, or individual level. In most cases, the overall diagnosis of a national or regional innovation deficit is immediately accompanied by a range of specific sub-diagnoses about where exactly institutions, policies, or societies are failing to live up to the innovation imperative – whether through a lack of science, technology, engineering, and mathematics (STEM) education, insufficient private sector expenditures on research and development (R&D), risk-averse attitudes, excessive regulation, or inadequate government incentives. For example, in 2015 the *Washington Post* declared that "Europe's innovation deficit isn't disappearing any time soon," blaming over-regulation and lack of harmonization across the continent (Downes, 2015). The Canadian newspaper *The Globe and Mail* ran an article titled "Government can't solve Canada's innovation deficit," which pointed to a lack of private R&D spending and misguided hand-picking of technologies by the government (Yakabuski, 2015). That same year, the Massachusetts Institute of Technology (MIT), in conjunction with the American Association for the Advancement of Science and the Alfred P. Sloan Foundation, released a report "The Future Postponed: Why Declining Investment in Basic Research Threatens a U.S. Innovation Deficit" (MIT, 2015).

According to the DMI, these diagnosed deficits require policy action. This action typically takes the form of innovation strategies or

Table 1
Comparison of the deficit models in PUS and innovation.

Elements of the "deficit model"	Public understanding of science (PUS)	Innovation
Problem diagnosis	Scientific illiteracy; irrational anti-scientific attitude or fear by the public	Lack of innovation capacity (national, regional, organizational, individual); lack of appreciation of the importance of innovation
Proposed solution	Science education and communication; "more science" as the panacea	Innovation strategies and entrepreneurship; private sector orientation; "more innovation" as the panacea
Source of expertise	Scientists	Innovation experts, e.g., academics, entrepreneurs, leading innovative institutions
Knowledge order and political order	Scientific knowledge trumps lay knowledge; technocratic governance trumps democratic and unruly politics	Economically useful knowledge trumps "pure" knowledge; innovation policy guides all other forms of policy
Standard for success	Threshold: scientificness (e.g., scientist-like literacy or certified politics)	Open-ended: competitive benchmarking along numerous innovation indicators

initiatives, many of which have been proliferating around the globe (Pfotenhauer and Jasanoff, 2017a). These strategies provide more or less concrete *remedies* to tackling innovation deficits. For example, the OECD Innovation Strategy (2010) recommends a range of actions, including moving "beyond supply-side policies focused on R&D and specific technologies to a more systemic approach," adapting "curricula and pedagogies […] to equip students with the capacity to learn and apply new skills throughout their lives," or making "migration regimes for the highly skilled [more] efficient, transparent and simple and enable movement on a short-term or circular basis." The report, *Innovation Canada: A Call to Action* (Jenkins et al., 2011), calls for the government to, among other things, "create an Industrial Research and Innovation Council (IRIC)" or "simplify the scientific research and experimental development (SR&ED) program by basing the tax credit for small and medium-sized enterprises (SMEs) on labour-related costs." More generally, with its drive toward innovation policy action, the DMI reveals a distinct pro-innovation bias that tends to sideline questions about why social challenges are problems of innovation in the first place or what alternative framings might exist. Likewise, it rarely asks about the broader social consequences of enacting measures such as altering immigration or tax policies in the name of innovation. Like the DMS scientism, it seems "irrational" to oppose initiatives that foster innovation, which appear as the most legitimate way forward.

Like PUS, too, the DMI emphasizes the value and critical importance of particular forms of *expertise*. Innovation itself has grown into a highly technical discourse, rife with its own experts, instruments, and metrics. A growing number of specialized academic journals currently address a broad range of questions and disciplinary perspectives on innovation and have contributed to the emergence of the field of "innovation studies." Some scholars have pointed to the emergence of a "new disciplinary tribe" of Innovation Studies (Godin, 2014) or traced the emergence of innovation as a distinct form of expertise in the United States (Wisnioski, 2015). International organizations, spearheaded by the OECD, have developed a vast array of comparative innovation indicators, policy manuals, and catalogues of innovation instruments. Successful technology entrepreneurs are widely perceived as authorities on a wide range of public problems that may be solved through innovation, including Peter Thiel, Elon Musk, and Mark Zuckerberg (Pfotenhauer and Juhl, 2017). What is more, a number of regions and institutions – such as Silicon Valley and MIT – have emerged as global reference points for how to be innovative (Pfotenhauer and Jasanoff, 2017b). This emerging expert–lay distinction grants disproportionate power to those who speak on behalf of innovation's transformative power.

In this sense, innovation has ceased to be a purely analytic concept used to explain sociotechnical change and economic growth. Rather, it is a policy goal and a professionalized discourse that is reshaping society in fundamental ways. In particular, the prevalent theorization of innovation as a systemic phenomenon has argued that innovation requires a concerted effort from all other policy domains to flourish. Other policy domains – such as research, education, taxation, immigration, or environmental policy – are increasingly reframed under the DMI, making innovation, in effect, a meta-goal of public policy. To optimize innovation, therefore, innovation policy and its rationales are granted the power to redefine the importance and activities of other social institutions.

The DMI restructures social and epistemic orders in yet another way. Decades' worth of innovation research have emphasized – and perhaps monopolized – the theorization of innovation as a techno-economic phenomenon (Godin and Lane, 2013; Pfotenhauer and Juhl, 2017). As a result, innovation is seen as desirable not just because of the ways in which technologies enhance our society. Instead, it is equally desirable because it is a major driver of economic growth and hence a key site of global competition (Romer, 1990; Scherer, 1999; Schumpeter, 1934). Electric cars, for example, promise not only cleaner mobility, but also a new car industry that guarantees employment and taxes for generations to come. This dual legitimacy of problem solving and economic prosperity contributes to a situation where innovation can continue to be desirable in economic terms even when the social consequences are questionable or highly disruptive. It is partly through this appeal to competition pressure and a "rising tide lifts all boats" rhetoric of economic growth that makes innovation automatically seem plausible and desirable, and that regularly serves to shortcut political debates about desirability.

Both the primacy of economic growth and the policy framing around (national or regional) systems helped establish innovation as an essentially competitive process. *Success* is measured principally in comparative terms in relation to other nations' innovation performance. This competition logic is consistent with a broader shift toward benchmarking as a modus operandi in public policy, where progress is typically measured through various "performance gaps." Benchmarking practices make it possible to present innovation as a matter of "catching up," "falling behind," or "staying ahead," which in turn feeds into "innovation deficits" and "emergencies." It also resonates with the Darwinist logic of "survival of the fittest" that underwrites evolutionary thinking in innovation theory and concepts such as "disruption" and "creative destruction." A comparison of deficit logics in PUS and innovation can be found in Table 1.

3. Exploring three sites of deficit construction

This section provides three empirical examples of the DMI "in action." The examples – three recent innovation strategies from Luxembourg, Singapore and Denmark – illustrate how, in each case, an imperative for innovation was diagnosed in conjunction with several specific innovation deficits. Moreover, they show how innovation featured as the solution to a range of social problems and, in the process of implementing the strategy, reconfigured social order in sweeping ways.

The case studies are based on a range of empirical materials, including an in-depth literature review of policy documents and secondary literature, ethnographic fieldwork, and 40 semi-structured interviews with actors between 2010 and 2016, including policy-makers, researchers, students, project managers and institutional leaders.[2] We use inductive, qualitative research based on a quasi-comparative case-study design (Eisenhardt, 2007; Jasanoff, 2005c), a discourse-analytic approach (Fairclough, 2013) and an interpretive "thick" cultural and policy analysis (Fischer and Forester, 1993; Yanow, 2000). Note that our research was not conceived as a strict comparative study that defines in advance the variables of systematic variation against the background of a fixed context. Rather, quasi-comparison became a method of choice to address similar questions and insights that emerged during three independent case studies. Our case studies thus serve both to validate our proposed analytical framework for the DMI and demonstrate its analytical utility.

3.1. Addressing an aging economy and society in Luxembourg's life sciences strategy

At first glance, the small, politically stable and exceedingly wealthy country of Luxembourg hardly seems to require any repair. Indeed, in a brochure seeking to attract businesses to the country, the Ministry of the Economy reflects on the Grand Duchy's success across a range of different indicators: "The country has one of the highest standards of living in Europe, low inflation, low unemployment, competitive corporate and personal income taxes, low public debt and a balanced budget. These policies result in a 'AAA' rating from all three major credit rating agencies" (Luxembourg for Business, 2015, p.4). Nevertheless, Luxembourg launched an innovation strategy in the life sciences in the first decade of this century that was deliberately aimed at addressing some purported deficits of the country's economic and demographic structure. In particular, biomedical innovation was framed as the solution to a set of three anticipated threats, forming "a three-strand policy of promoting research, encouraging economic diversification and fostering health benefits for society" (Luxinnovation, 2010, p.28).

These three strands of the initiative were positioned as responses to three forms of deficiency that had been ascribed to Luxembourg from the 1990s onwards. First among these was the lack of diversity of Luxembourg's economy. The country relied heavily on banking and logistics, with little in the way of a manufacturing industry or promising outlooks for an internationally competitive "knowledge economy." Another deficit constantly invoked in Luxembourg's innovation strategy was the small size of the country. Interview informants particularly linked this deficit to difficulties in developing enough scientific capacity within the country's borders, and to the absence of a domestic market for the products of innovation. Finally, the aging of the population and associated concerns about rising health-care costs formed a third deficit to which investments in the life sciences were considered a promising response.

An investment of EUR140 million in the life sciences, launched in 2008, formed Luxembourg's remedy to these deficits. As a policy official recollected in an interview, the life sciences were considered a domain that could address each of the specific problems of economic diversification, building up scientific capacity and making health care sustainable for an older population. Moreover, there was a general sense that innovation capacity in the life sciences was something that Luxembourg could ill afford to miss out on. As one ministerial official explained in an interview, "nowadays, biotechnologies are so pervasive and if, as a country, you don't have a minimum understanding and skills for it, you are going to lose in many areas." With significant financial commitments, the government of Luxembourg developed various initiatives, including the establishment of various new research institutes such as the Luxembourg Center for Systems Biomedicine (LCSB), a biobank and a life sciences research unit at the country's young university. An important step in enhancing science in Luxembourg was to attract biotechnology companies from abroad by presenting Luxembourg as an "ideal gateway to the European market" (Luxembourg for Business, 2015, p.2).

Luxembourg drew on various forms of expertise in establishing its biomedical sector. Consultancy firm PricewaterhouseCoopers played an important role in first developing the Luxembourg initiative, and would later brand it as one of "ten significant events for personalized medicine" (PwC, 2009, p.39). However, the life sciences sector was not a self-evident choice. Research in this field in Luxembourg was insufficient and "[had] no critical mass," according to one ministry official. The initiative therefore needed to "take a bet and focus on a specific field, […] look where we have competence [and] pick the diseases." This resulted in an initial focus on "national priority areas of direct interest to citizens: cancer, diabetes and Parkinson's disease" (Luxembourg for Business, 2015, p.14). This focus on existing areas of research formed a second important form of expertise, yet this was further enhanced by actively seeking assistance from abroad in developing research capacities that were not yet present in Luxembourg. The U.S.-based Institute for Systems Biology was central in setting up the strategy and the LCSB in particular – as were other initial and ongoing collaborations and exchange programs with (especially) U.S. research institutions.

The pursuit of innovation in the life sciences reflects particular ideas about the social future that Luxembourg should aspire to. Innovation in the life sciences – and in systems biology and personalized medicine in particular – is considered to be able to provide a solution to the growing pressure on the country's public health-care system. This solution takes the form of more tailored diagnosis and treatment for individual patients, and less waste of resources on treatments that may not work. Furthermore, as a researcher in the study argued, it will help Luxembourg's society make the necessary shift to a knowledge economy: the biotech strategy "for sure, is [about] stimulating biotech stuff, but I think it is also about [putting] science into the Luxembourgian mind," the researcher explained. According to him, Luxembourg should become a more scientifically advanced country across all levels of the population and he considers the LCSB "a lighthouse […] a nucleus for increasing science development" in that context.

The life sciences strategy thus simultaneously seeks to establish a frontier field of scientific research and innovation in Luxembourg, and Luxembourg itself as a serious competitor at the frontier of this field in Europe. However, while acknowledging that Luxembourg has little direct expertise in this domain, interview respondents emphasized various characteristics of the country – including some of the deficits – as markers of the likelihood that Luxembourg would succeed. Among them were not only existing strengths such as expertise in (banking) data security, logistics, and the "right" distance to big pharma in France and Switzerland ("you can go there in a day, but you don't have to mix that much," as one interviewee remarked), but also the absence of a vested interest, which supposedly makes radical innovations possible.

Perhaps symbolizing the ambitions and novelty of the initiative best, Luxembourg's life sciences campus was built on the site of a

[2] Our discussion of the life sciences strategy in Luxembourg is based on three interviews conducted by EA in the summer of 2013 with informants who had been involved in the life sciences strategies as policymakers, administrators and biomedical researchers. For the Singapore case we conducted approx. 25 interviews between 2010 and 2014 with actors involved in all of the Singapore–MIT partnerships and the institutional and policy landscape of Singapore. Interviews were carried out by SP both at MIT and in Singapore. In addition, SP spent approximately two years as a participant observer in various MIT international partnerships, granting him wide access to members of the MIT international ecosystem, meetings, and internal strategy documents. The case of Danish science governance and Danmarks Tekniske Universitet was based on various episodes of ethnographic fieldwork between 2010 and 2012, combined with 12 contextual interviews with students, academic researchers and educators, and lower-level academic managers.

decommissioned steel mill in the south of the country. As a research administrator described this location: "This was a big steel mining area […] it was given to the country to use for whatever they wanted. It is an opportunity to have such a big space to build something from scratch." Nevertheless, the country's bet on biotechnology gives a very particular shape to its imagination of the future. Placing the research campus at this particular site may be understood as symbolic not only of an economic reorientation or a scientific clean slate, but also of an imagination of technological substitution that leaves out other choices that might be made to enhance the country's scientific status or future health system – choices that are essentially political in nature.

3.2. Addressing innovation deficits through imported "best practices": Singapore's partnerships with MIT

Like Luxembourg, Singapore is not typically associated with a deficient economy. Unlike the Grand Duchy, however, Singapore's current economic success rests on a recent and rapid development trajectory centered on technology and manufacturing, which catapulted the city-state from a colonial trading port to an eminent global knowledge economy.

After its independence in 1965, and building on its trading port heritage, Singapore positioned itself as the "Gateway to Asia" and subsequently became a manufacturing and logistics hub for multinational corporations (Huff, 1995; Keen Meng, 2010). Singapore's rapid industrialization first ran into problems in the mid-1970s, when rising living standards and the small labor force could no longer sustain competitive low-cost manufacturing. Consequently, the government decided "to phase out its labor-intensive industry and focus on skills-intensive, high-value-added, technology-intensive industries such as electronics manufacturing, data storage, and petrochemicals" (Chuan Poh, 2010). Yet, in the 1990s, the country again began to experience the limits of the "Asian growth miracle" (Krugman, 1994), which economists largely attributed to a deficit of an endogenous science base and innovation. In response, the government turned outward and began importing "best practices" from places like the U.S., Hong Kong, Switzerland, Israel and others (Pfotenhauer and Jasanoff, 2017a).

A case in point for these imported solutions to the perceived innovation deficit are Singapore's partnerships with MIT (Pfotenhauer et al., 2016). The first major agreement, the Singapore-MIT Alliance (SMA), was launched in 1999 primarily as an educational collaboration trying to address a lack in "talented human capital for Singapore's industries, universities, and research establishments" by "[attracting and retaining] the very best engineering and life sciences graduate students and researchers from across Asia" (SMA, 2005). According to one senior institutional leader, Singapore was "starting from far behind the curve compared to other countries." SMA was implemented through Singapore's two main public universities – the National University of Singapore (NUS) and Nanyang Technical University (NTU) – but breaking with their traditional departmental and disciplinary structures. Instead, the program emphasized interdisciplinary, research-intensive graduate programs with a strong application orientation modeled after MIT practice, which the government considered to be missing in Singapore.

By the early 2000s, that deficit diagnosis had noticeably shifted. Biotechnology was on the rise and was considered a more promising and innovative field than microelectronics and machinery. Yet local biotech capabilities were arguably low. Aiming to keep up with leading innovative regions around the world, Singapore thus begun moving heavily into the life sciences (Chuan Poh, 2010), accompanied by an image shift from "intelligent island to biopolis" (Clancey, 2012). Again, MIT was selected as the expert partner of choice to help close the innovation gap: in 2003, Singapore extended the partnership with MIT to a second phase (SMA2). However, it replaced many of the previous focus areas that had sustained Singapore's prior successes (mechanical and electrical engineering) in favor of life science research and education.

In 2006, MIT and Singapore signed yet another agreement with an equally strong focus on the life sciences – the Singapore-MIT Alliance for Research and Technology (SMART). In contrast to SMA, SMART did not offer educational programs but aimed to attract and retain foreign world-class researchers to conduct research *in Singapore* and *on Singaporean topics*. MIT faculty were expected to spend at least one year out of a five-year engagement in residency. In exchange, faculty received considerable research funding, their own local laboratories and research staff, and support for local collaborative projects. A senior manager at SMART explained: "Singapore, as a small country, will never have a human resource base large enough to address all its problems itself and achieve excellence in all fields. [It cannot wait] until it has grown [a domestic research talent pool] before we can do significant research." Importantly, SMART was located outside NUS and NTU and was funded as a separate unit by the National Research Foundation. This move responded to a growing sense that bureaucratic constraints at these institutions were a main factor hampering innovation and entrepreneurship. A dedicated translational unit was established by SMART (the SMART Innovation Centre), modeled after MIT's Deshpande Center, to address these perceived deficits, further deepening the institutional rift.

In the late 2000s, Singapore's innovation imperative took yet another turn. Insufficient engineering capability was no longer seen as the main barrier to innovation by policy circles. Rather, it was a lack of creativity that hindered the transition "from efficiency-driven growth to innovation-driven growth" (Remaking Singapore Committee, 2003; Tan and Phang, 2005). Moreover, Singapore's existing excellent institutions, NUS and NTU, were deemed relatively ill-suited to attempt a fundamental overhaul in undergraduate education. In early 2010, the government of Singapore thus resolved to establish the new Singapore University of Technology and Design (SUTD), again with the help of MIT. SUTD was heralded as a decisive break with the established research and education landscape – "something different from the existing institutions," according to Singapore's prime minister (Lee, 2015). A small, elite university focused on design thinking, creativity, cohort-based learning and, above all, innovation, SUTD was conceived as a remedy to the perceived shortcomings. MIT faculty were instrumental in developing infrastructure, focus areas, and organizational routines. At SUTD's inaugural, MIT institute professor and former dean of engineering, Tom Magnanti, suggested that "SUTD's aspirations are no less [than MIT's]. […] Through creative research and education anchored on technology and design, SUTD aims to create a new type of technically grounded leader and inventor, one fully equipped to address the challenges and issues of today and tomorrow."

Taken together, the four partnerships, SMA, SMA2, SMART, and SUTD, speak to a constantly shifting but never quite disappearing deficit diagnosis around innovation. Curiously, MIT was brought in multiple times to supplant seemingly outdated versions of innovation "best practice" that it had previously helped shape and consolidate. The locus of innovation gradually shifted away from established universities toward new institutions, even though alternative paths were certainly possible (as demonstrated by SMA). It also meant embracing some areas (biotech) while scaling down others (mechanical engineering). Moreover, it cemented a strategy of linking Singapore to leading innovative regions around the globe rather than collaborating with its nearest neighbors.

To some extent, Singapore's strong outward orientation and obsession with importing cutting-edge practices is not surprising: a small city-state with no agrarian hinterland, no natural resources and a comparably small population, Singapore has long mobilized a deficit narrative to justify its policies on technology leadership and global economic ties. From the start, Singapore aimed to compensate for its size and resource disadvantages by positioning itself as an essentially "global city" – "a new form of human organization and settlement [that] could make up for its traditional disadvantages of size through such newly forged alliances," according to one of Singapore's most famous ideologues (Rajaratnam, 2007). From a security standpoint, global innovation alliances are also an insurance policy for the city-state that forces international institutions to have “skin in the game” in Singapore’s future, which still recalls a brief and turbulent merger with Malaysia in 1963. Innovation deficits, in this sense, are at the same time security deficits that make it possible to marshal resources and build national cohesion around an unwavering agenda of development for sustained independence.

3.3. Rectifying deficient science in 21st century Denmark: university reforms at Danmarks Tekniske Universitet (DTU)

In 2001, the Danish Liberal Party won the election partly on the promise to boost Danish innovation and, more generally, the Danish national economy through the privatization of public sector services, which were portrayed as deficiently ineffective and costly. Anders Fogh Rasmussen, the newly elected prime minister, was known in Danish politics for co-authoring the book *From Social State to Minimal State,* in which he drew substantial inspiration from American political philosopher Robert Nozick. In his book, Rasmussen took a decidedly neoliberal approach that diverged from the ideas of solidarity, social security and cultural diversity upon which Denmark had built its public sector after the Second World War. In contrast, he argued that “there exists only one useful measure of reward: What is the product or service worth to other human beings? […] The one who is less good will receive a lesser reward. The free market will determine the size of the reward. Market reward is neither right nor wrong nor just or unjust. It is simply a fact”[3] (Rasmussen, 1993, pp. 80–81). In the ensuing neoliberal reforms following the elections, all public institutions were scrutinized in terms of their economic viability and managerial efficiency, heeding expert advice from the New Public Management movement (Lynn, 1996; Pollit, 1993).

Within the university sector, Rasmussen’s ideology was implemented through a range of reforms that sought to professionalize universities and gear them toward innovation. Under the famous 2000s slogan, “From Research to Invoice,” the Liberal Party’s message to Danish research institutions and their employees was clear: the solution for Danish university science was commercialization.

DTU, Denmark’s flagship institution for technical science was hit first. Predating the 2001 election, the university had faced severe economic problems including declining student numbers, shrinking budgets, and even the risk of bankruptcy, all of which threatened the existence of the prestigious institution. In the late 1990s, the once-sacred research institution found itself cornered in a revitalized political game concerning its control. The DTU Konsistorium, which had been the highest decision-making authority in Danish universities since the founding of Copenhagen University in the 1540s, was confronted with a tough decision: either face severe cutbacks or accept a deal that was secretly negotiated between the then-DTU president, Hans Peter Jensen, and then-Minister for research, Birte Weiss. “I feel severely cheated and deceived, when I as member of the highest body did not receive the note,” Konsistorium member John Madsen replied after secret notes on DTU’s new organizational structure later emerged (Forsker Forum, 2001, p.1). The solution that was adopted in the 2001 “DTU Law” effectively replaced the Konsistorium with an executive board of externally appointed directors and did away with the substantive representation of students and non-academic staff (25% each) that had become integral to the “collegiate system” that was introduced after the 1960s student riots to constrain professorial power. The new law gave the DTU president almost complete autonomy and unrestricted authority. It also turned the public institution into an autonomous enterprise and replaced the democratic collegiate system with a top-down hierarchy of appointed leaders, rigid accountability standards, and an executive board with a majority of external members – predominantly appointed from private industry (Carney, 2006). While the deal tentatively alleviated DTU’s financial troubles, it was also seen by many as the beginning of the end of academic self-governance in Denmark: “The politicians have intervened more in the universities’ self-governance, in such a way that the conditions for both teaching and research are subjected to tighter political control in a world where the private labor market experiences more and more decentralization,” noted Leif Søndergaard, president of university educators at the Danish association of Masters and PhDs (Forsker Forum, 2001, p.6).

2001 was also the year in which the Researcher’s Patent Law[4] was introduced to make publicly funded research patentable by the research institutions, which in turn were obligated to exploit commercial potential through technological innovation. In 2003, the subsequent reform “Time for transformation of Denmark’s universities,” which carried the subtitle “Strengthened leadership, increased freedom, stable economy,” opened up the remaining Danish universities to the possibility of reorganizations similar to those implemented at DTU. Both the governance principles and the legal basis upon which science operated in Denmark were thus fundamentally rewritten in the name of a particular (commercial) vision of innovation. The 2003 reform effectively displaced the universities’ mechanisms of accountability, no longer referring to science’s internal criteria but instead catering to the criteria of non-scientific (and primarily economic) recipients of scientific results (Carney, 2009; Juhl, 2016).

Interestingly, despite the overt deficit construction around innovation, economic impact, and governance efficiency to justify major institutional interventions, a major study conducted in 2013 based on interviews of 70 actors from universities, industry, and government concluded that the Danish efforts to commercialize science from 2000 to 2010 had produced more expenditures than they had generated income (Norn et al., 2013). Moreover, according to the *Times Higher Education*’s World University Ranking, DTU scored a remarkable 98.1 out of 100 on “Industry Income” in 2015, while its scores on “Research” and “Teaching” dropped to a remarkably low 28.2 and 39.9 out of 100, respectively. Corroborating this tendency, a senior manager at DTU Management confirmed that in hiring situations they look for candidates’ “possibilities for direct (and paid) industry-collaboration.” In contrast, early career researchers at DTU Management responded that much of the industry collaborations did not turn into publishable research results.

The shifts from scientific self-governance to economic productivity observed in Denmark since the 1990s are not an isolated incident, but speak to a broader reconceptualization of the value, social purpose and political legitimacy of science in universities in the 21 st century. Polanyi’s (1962) famous notion of an autonomous Republic of Science – a governance model where “any authority which would undertake to direct the work of the scientist centrally would bring the progress of science virtually to a standstill” – has become a liability under the aegis of the innovation imperative (especially in an era of New Public Management). Although the public tone toward Danish science remained polite, the collegial system’s liquidation reconfigured the normative space that defined the social purpose of science and the legitimate modalities of knowledge production. These reconfigurations are in alignment with “Mode 2” science’s “new production of knowledge” (Gibbons et al., 1994) and the Triple-Helix model (Etzkowitz, 2008) for the new production of innovation (i.e. through university–government–industry interactions) (Juhl, 2016). Closer attention to the explicit and tacit deficit constructions at play here can help us to understand the implications of such value assessments based on economic utility for the moral status of science and its governance structure.

[3] Translation from Danish by JJ.

[4] Translated from the Danish *forskerpatentloven*.

Table 2
The deficit model in three countries.

DMI	Luxembourg	Singapore	Denmark
Problem diagnosis	Economic basis at risk; Little critical research mass; Aging society and public health	Repeatedly shifting deficit diagnoses in rapidly evolving innovation system; Technology-based economic growth needed to compensate size, resources, and security deficits	Little economic productivity and university accountability; Science as unexploited economic resource
Solution	Bio-innovation hub; Gateway to Europe; Tie into global bio-economy	Import of innovation "best practices"; Adjustment of technological and educational priorities	Repurposing of science as economic asset; Overhaul of university governance
Source of expertise	PwC; international institutions	MIT; perceived global "best practice" models	(Neoliberal) New Public Management theories
Knowledge order	Primacy of life sciences and biotech innovation	Primacy of new institutional spaces over existing ones for interdisciplinary education, tech transfer, creativity and gradual social reform	Primacy of industry collaborations, economic utility of knowledge and top-down management
Standard for success	Open-ended: future-proof knowledge economy (esp. bio-economy); potential solution to demographic challenges	Open-ended: repeated benchmarking with MIT; competition and projection of strength towards neighboring countries	Open-ended: economic viability (business model) for university; global economic competitiveness

4. Discussion: The invisible politics of the innovation imperative

The above case studies illustrate how the "deficit model of innovation" has become a powerful justification and organizing principle for major institutional and policy interventions. All three countries subscribed to the globalizing "innovation imperative," yet each did so in its own way, pointing to unique social, economic, and institutional deficiencies and taking different courses of action. Our comparative analysis revealed the different dimensions of deficit construction and thus helps shed light on the discursive and political dynamics underwriting innovation policy in each case (see Table 2).

First, in terms of problem diagnosis, the particular deficits identified are quite diverse and may combine seemingly disjointed socio-economic elements. In Luxembourg, uncertainty about the economic future, demographic change and its consequences for public health, and the absence of a critical mass in research were all considered part of the same compound innovation problem. Singapore turned to innovation not only to systematically address perceived deficits in education, research, institutional design and scientific culture more broadly, but also in response to perennial concerns about the country's geopolitical survival. In Denmark, the innovation imperative imposed on the country's universities sought to develop science as an economic resource and simultaneously to make universities more productive and accountable.

Policymakers turned to equally diverse strategies to address the perceived problems while justifying them in the name of innovation all the same. Thus, innovation leadership was to be achieved, in Luxembourg, through developing capacity in the life sciences that could be plugged into European biotechnology markets, in Singapore, through importing various innovation "best practices" from abroad, and, in Denmark, through institutional reforms "from research to invoice." All three countries turned to specific (and different) forms of innovation expertise, including an international consultancy firm in Luxembourg, the globally renowned innovation powerhouse MIT in Singapore and New Public Management approaches in Denmark. In each country, too, we saw how policymakers chose to address social problems through an innovation strategy, thus giving innovation primacy over other forms of policy intervention in the shaping of social order. In Luxembourg, biotechnology investments (rather than, say, an expansion of social services) were the vehicle of choice to tackle the challenges of an aging society. In Singapore, new institutional spaces for creativity and entrepreneurship were created in the name of innovation, rather than overhauling existing institutions. In Denmark, financial stabilization of DTU was coupled to an innovation agenda, even though it could have happened another way.

The cases further illustrate that innovation success is understood in a comparative and fundamentally open-ended manner. Unlike the idea of discernible "scientific literacy" in PUS, there is no threshold for "innovation literacy." Rather, innovation deficits and successes are always understood vis-à-vis global competitors. Luxembourg sought to secure a sustainable future as a competitive knowledge- and bio-economy that positioned itself ahead of other nations as a gateway to Europe. Singapore consistently benchmarked itself vis-à-vis the latest MIT innovation practices. Denmark demanded scientific and economic competitiveness from its research base, benchmarking it against private-sector efficiency. This competitive benchmarking dynamic suggests that deficit remedies are at best temporary: caught in a self-reinforcing dynamic of catching up/staying ahead, the innovation imperative will never come to a conclusion. Even highly advanced nations such as Luxembourg, Singapore, and Denmark consider themselves at constant risk of falling behind.

There are, of course, limits to our comparative study: for example, one must be prudent when comparing different sectors, e.g., a national biotech policy in Luxembourg as opposed to university reforms in Denmark. Our cases also cut across multiple scales (national, regional, and institutional). For example, national innovation strategies in Luxembourg and Singapore included the establishment of new research institutions, and the Danish university reforms were linked to a broader shift toward neoliberal governance for the country as a whole. Likewise, while all three countries are relatively small, the difference between the bustling city-state of Singapore and Denmark's economically significant agrarian hinterland are quite large.

Nevertheless, our cases illustrate how the innovation imperative and associated notions of innovation deficits permeate a wide range of policy domains and social contexts. Moreover, they reveal how different political cultures, steeped in different socio-economic histories, interpret and act upon the perceived innovation imperative in very different ways. These idiosyncratic ways of understanding what innovation requires and how it fits into the local institutional landscape resonate with what Pfotenhauer and Jasanoff (2017a) call "Imaginaries of Innovation." From this vantage point, the case study in Luxembourg reveals how innovation relates to the country's current economic structure based on financial services, a strong welfare state and its outlier role within Europe. Likewise, the life sciences strategy in Luxembourg reflects a national self-understanding that the country is at the geographical, cultural and linguistic heart of Western Europe. The Singapore case speaks to the malleable role of research institutions in the rapidly developing innovation system of a country known for its technocratic systems approach to governance. It also shows Singapore's preoccupations with economic and technological advancement as a means for security and social reform, as well as a long tradition of overseas linkages. The Denmark case stands apart as an example of commercial reorientation of university research that has to be evaluated against the country's democratic and welfare traditions. It also shows how an overt push for application and commercialization in the name of innovation can lead to considerable resistance.

These findings speak to the hidden politics of the innovation imperative: in each of our cases, the innovation policies introduced fundamentally altered the premises under which existing institutions could fulfill their societal functions – frequently in ways that marginalized any rationales and values other than innovation for framing and tackling social problems. Moreover, these innovation strategies were rarely deliberated on as *political* decisions that touch upon a range of institutionalized social norms and values with potentially large consequences. For example, in the case of Luxembourg, should welfare states really bet their future on transnational biotechnology markets? What type of biotech does Luxembourg's society find acceptable? And is an aging population really an asset? In Singapore, should a national flagship institution be included or sidelined in reforms? Is a research strategy based on importing foreign researchers really more desirable than a strategy based on homegrown talent? And does the shift from electronics manufacturing to biotech benefit the majority of the workforce? In Denmark, what is the role of universities within society – are they commercial enterprises pursuing returns on investment or cradles of civic emancipation and social upward mobility? How should universities be governed? And is research really worth funding only if it is commercially applicable? These questions underscore the need to understand innovation policy as essentially political: while all three policy strategies may indeed have promoted innovation, they also broadly intervened in existing social and institutional orders with consequences far beyond what their narrow focus on technological innovation betrays. Alternative priorities and courses of action were conceivable in each case, but rarely openly deliberated and generally outweighed by the perceived competitiveness pressures and the authority of innovation expertise.

Against this background, we end on a word of caution. The similarities between DMS and DMI in terms of technocratic governance and a lack of institutional reflexivity suggest that continued blind adherence to the present deficit logic may result in the widespread erosion of public trust and credibility with regard to innovation policy. While the need for dialogue and inclusion has made some headway into mainstream policy discourses in science and technology policy (Irwin, 2006), a similar appreciation is currently lacking in innovation policy. All three cases arguably suffered from an absence of inclusive, deliberative processes about the desirability of the proposed changes and a recognition that innovation strategies, too, are a form of politics that require legitimacy. Without public legitimation, innovation policy may remain unable to better connect innovation to societal needs (Kuhlmann and Rip, 2014) or effect directed transformative change (Schot and Steinmueller, 2016). The continued deference to a global innovation imperative obscures the political stakes and diverse needs across diverse contexts and distracts from potential negative or disruptive social consequences of innovation. Thus, Wynne's question (1992) as to whether we are truly approaching "new horizons" or are caught in a "hall of mirrors" rings as true for innovation policy today as it did for PUS in 1992. By imagining innovation under wider horizons, we may begin to conceive of more democratic forms of innovation policy.

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