INNOVATION POLICY IN THE AGE OF TRANSITIONS

How a socio-technical understanding of innovation can inform international initiatives at the intersection of innovation policy and climate action

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**1. Introduction**

Modern societies are faced with a set of interconnected grand challenges that are deeply rooted in our production and consumption patterns (Elzen et al. 2004). As a result, there is a growing awareness that fundamental and persistent change across society is needed to address these challenges and make economies socially, economically and environmentally sustainable. This has led to a prominent policy discourse framed around the need for ‘transitions’ or ‘transformations’ of entire societal systems, such as energy, mobility, housing, health and food (Steward, 2012)

The need to transition these established societal systems into environmentally and socially sound ones without impeding economic development is a formidable task, which runs counter to the idea of the process being manageable from a single point or to be understood in a linear and rational way (Geels and Schot 2007). In addition, prevailing approaches that focus on addressing market failures and individual behaviour do not sufficiently address the structural entrenchment of grand challenges, which arguably needs to be augmented by a more complex and heterogeneous set of measures (Steward 2012). Hence the intricate relationship between economic development and sustainability presents a dilemma on how to produce an adequate policy response to grand challenges, which in a finite world are likely to exacerbate in the future (Rockström 2009)

Accordingly, alternatives are advanced by policy makers and academics from the STI (Science, Technology and Innovation) community who have increasingly taken an interest in exploring the transformative potential of innovation. Policy makers are not only interested in the pace and scale of innovation, but also in its direction and related normative questions. These are expressed in discourses around, among others, inclusive innovation (OECD, 2016), social innovation (Murray at al, 2010), challenge-led innovation (Steward, 2012), mission-oriented innovation (Mazzucato), system innovation (Geels), eco-innovation (Kemp) and responsible research and innovation (Owen et al, 2012). Rather than presenting incremental additions to an otherwise stable policy domain, we argue that these recent developments are signs of an emerging third generation innovation policy, hereafter called transformative innovation policy, which can be seen as being layered upon but not fully replacing the first generation of science & technology (S&T) policies and the second generation of innovation systems (IS) policies (building on a.o. Borras, 2003; Borras 2007; Fagerberg 2006; Lundval 2007; Kemp 2011; Kallerud 2010; Kallerud, 2013).

This opens up a new ‘discursive space’ for innovation policy that is currently being occupied by different academic groups that either speak of green products or industrial ‘revolutions’, socio-technical ‘transitions’ or broader societal ‘transformations’. Rather than attempting to equate them, we conceptualise transformative innovation policy as a new (and third) generation of innovation policy that draws on a variety of different approaches. By doing so, transformative innovation policy encompasses both the technological aspects of grand challenges and corresponding need of science-driven R&D programmes but also includes a more broad-based agenda that aims to accelerate the diffusion of environmentally sound technologies into daily practices and different local contexts.

The aim of this paper is twofold. The first part is conceptual and presents a framework that helps to compare and contrast the consecutive generations of innovation policy *and* helps to create a better understanding of the different groups currently occupying this new space for innovation policy. The second part is empirical and identifies recent trends in innovation policy and focus on a number of international policy initiatives at the intersection of climate action and innovation policy and in particular ‘Mission Innovation’ launched at the 2015 United Nations climate change conference (COP21). The goal is to identify paradoxes and tensions between our conceptual analysis and our empirical observations and open up debate for way forward.

**2. Conceptual Framework**

**2.1 Two dimensions of innovation policy**

In his paper on the uptake of the broad systemic view on innovation, Edquist (2014) makes a strong argument that the understanding of the innovation process as such says nothing about the objectives of innovation policy. He argues that the two have to be separated as the ultimate objectives of innovation policy – the policy agenda – are determined in a political process. Kallerud (2010) makes a similar distinction by talking about vertical (understanding) and horizontal (objectives) dimensions of innovation policy. Smith et al. (2010) also make a comparable separation by discussing the analytical framework and problem definition of innovation policy. We base ourselves on this argumentation and argue that innovation policy can be separated along two dimensions based on the understanding of the innovation process and the corresponding policy agenda.

***Understanding of innovation***

Innovation can be portrayed as a process, referring to the various activities undertaken to bring novel products, processes or services into practice. There are many different views on how this process works, but a commonly found simplification in the literature is to distinguish between a broad and narrow understanding (SOURCES). In its extreme form, the narrow understanding sees innovation as the commercialisation of science with an active role for academia and industry where, in the words of the 1933 Chicago world fair slogan, “academia invents, industry applies and society conforms” (Rip et al, 2010). There is focus on R&D for the development of new technologies, the so-called ‘STI-mode’ (Jensen et al, 2007) and it is informed by the linear model of innovation. This model describes innovation as a journey from basic research, to applied research, to technology development and diffusion (Caraca et al, 2009). In this simple supply-push model, all innovation results from science and it is scientific advances that determine the rate and direction of innovation (Godin, 2013). This process is seen as being hindered by market failures, arguing that certain types of knowledge have the character of a public good and lead to knowledge spill-overs – i.e. other people benefiting from your work – resulting in an underinvestment in knowledge development (Woolthuis et al, 2005).

In contrast to this, a broad understanding sees innovation as an interactive learning process (Lundval et al, 1992) between a broad variety of actors (Carayannis and Campbell, 2009) that includes different types of knowledge and different modes of innovation (Jensen et al, 2007). It is informed by a systemic model of innovation acknowledging the complex networks of organisations and institutions that provides the environment in which innovations are developed, diffused and used (Fagerberg 2006). Innovation processes are therefore not only influenced by market failures but can also be hindered by system failures that lead to path-dependencies and increasing return to adoption and bring for example institutional or infrastructural lock-ins (Woolthuis et al, 2005). The broad understanding of innovation challenges the dominant role of science arguing that innovation needs to be appreciated as something much more than the knowledge transfer from science into commerce as not all innovations are science-based and only a few are science driven (Caraca et al, 2009). With science losing it royal position there are emerging literatures exploring other modes of innovation around not only science and technology but also doing, using and interacting, giving explicit attention to both the codified and tacit characteristics of knowledge (Jensen *et al.* 2007). Consequently, a broad understanding implies an open and networked view of the innovation process that pays more attention to the rich diversity of ‘broader’ non-technical innovation modes such as business-model innovation (Chesbrough, 2010), social innovation (Murray et al, 2010), institutional innovation (Hargrave and van de Ven, 2006), open innovation (Chesbrough et al, 2003) or user-led innovation (Von Hippel, 2005). Acknowledging different modes of innovation and types of knowledge implies that one should include a wider variety of actors and practices moving away from the tendency to focus on the ‘triple helix’ of universities, (high-tech) industry and government, taking on the direct engagement of a diversity of ‘social partners’ (Steward, 2012). Examples are non-market innovation actors such as cities, philanthropists, NGOs, ordinary citizens and users (von Hippel 2005) and a growing appraisal for the creative class, the entrepreneur, the artist and the designer and even the marketer (Bodin, 2008). This has also been labelled collaborative innovation (Baldwin and von Hippel, 2011; Granieri and Renda, 2012), collective experimentation (Rip et al, 2010), the quadruple helix (Carayannis and Campell, 2009) or the networked model of innovation (Fowles and Clark, 2005). Finally, the systemic characters and corresponding failures of a broad understanding of innovation have a strong spatial character (Coenen and Truffer, 2012) and as a result, innovation is often conceptualised as a situated process with strong place-based characteristics (Barca et al, 2012).

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| **Understanding of Innovation** | |
| **Narrow** | **Broad** |
| Innovation as the commercialisation of science | Innovation as an interactive learning process |
| Academia and industry as leading actors | A broad variety of actors with an active role for both government and civil society |
| Focus on R&D for new technologies | Different types of knowledge (tacit and codified) and different modes of innovation (STI vs DUI) |
| Informed by a linear model of innovation | Informed by a systemic model of innovation |
| Innovation is impeded by market failures | Innovation is impeded by both market and system failures |
| Innovation feeds in to a ‘global technology opportunity set’ | Innovation is often situated and has a strong place-based nature |

**Policy Agenda**

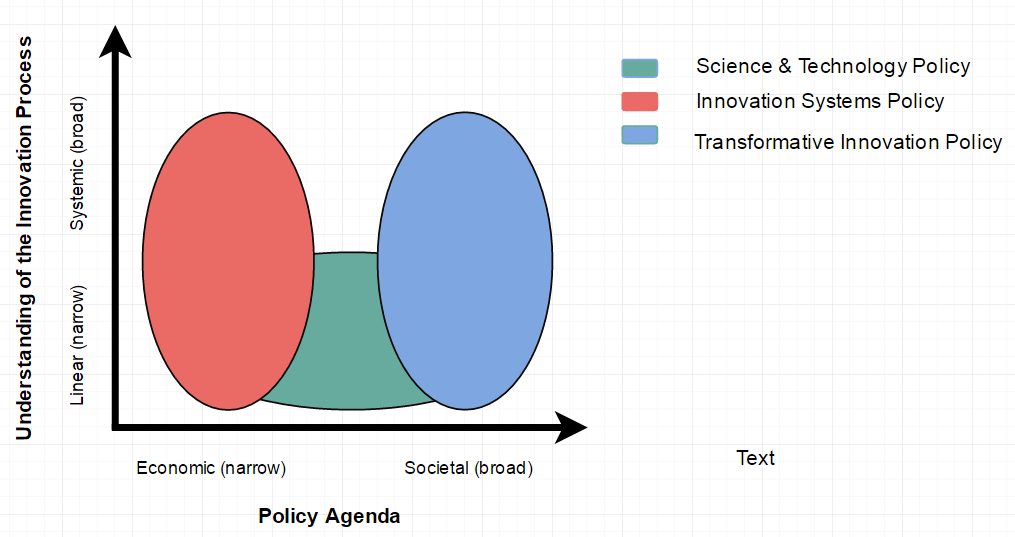
Innovation policy always has an ulterior motive, meaning that the ultimate objective of innovation policy is usually not innovation per se, but a secondary goal that is determined in a political process (Edquist, 2014). If innovation is considered as a means to an end, it is important to clearly define these ends (van den Hove et al, 2012). Again, we make a simplification between a narrow and broad policy agenda, where a narrow innovation policy agenda only informs economic or industrial policy and a broader societal agenda also informs other domains such as environment, energy, health, agriculture, etc (European Commission, 2002). In its extreme, a narrow economic agenda only focusses on competitiveness, jobs and growth with an implicit definition of innovation as solely a means of bringing product or services to the market (van den Hove et al, 2012). A broader societal agenda can be expressed in several ways, for instance by having an eye for the impact of innovation on other parts of society, or an agenda motivated by national prestige, strategic priorities or the need to address societal challenges (OECD, 2015). A broad societal agenda can also acknowledge the fact that not all.

innovations are inherently positive and can acknowledge negative outcomes as well (Sveiby et al, 2012). They acknowledge that it is difficult to include unintended and undesired aspects of an innovation, as it is already difficult to predict intended and desired outcomes. However, ignoring them is not a viable option. It will simply “make the minister of economy the minister of desirable outcomes of innovation, and the ministers of environment, social affairs and health the ministers of undesirable outcomes of innovation” (Sveiby et. al, 2012b).

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| **Policy Agenda** | |
| **Narrow** | **Broad** |
| Part of economic and industrial policy | Relevance for and impact on other policy domains |
| Sole focus on competitiveness, growth and jobs | additional objectives such as national prestige, strategic priorities or societal challenges |
| All innovation is good | Acknowledging negative outcomes of innovation |

**Framework**

By plotting the two dimensions – understanding of innovation and policy agenda – against each other one can create a framework, as done in Figure 1. The axes of the framework go from narrow to broad. Based on these dimensions, it is possible to find an endless number of understandings of innovation. However, for the sake of clarity we will focus on three broader generations of innovation policy. The next section will discuss them in more detail and explain their positions in the framework.



***Figure 1:* a framework for understanding innovation policy**

**3. Three generations of Innovation Policy**

Innovation policy is constantly evolving yet change usually does not happen in a linear fashion but goes through periods of both incremental and radical change (Sabatier, 1999). Although reality is often more complex than depicted in the literature, it is possible to distinguish three broad generations in which a particular policy domain remained relatively stable over time (e.g. Kemp 2011). Different generations of innovation policy are often not simply replacing each other but build on each other (Borras, 2007; Kemp, 2011). In line with Weber and Rohracher (2012) transformative innovation policy is also not replacing but complementing former generations of innovation policies.

**3.1 Science & Technology Policy**

Following our presented framework, the first generation of S&T policy making can be understood as having a narrow understanding of the innovation process. S&T policy was heavily influenced by a linear understanding of the innovation process, either through supply-push or demand-pull mechanisms. Focus was on technological knowledge production and R&D. Scientific endeavours around nuclear energy and space programs created a strong believe in the top-down centralised control of science that gave room to so-called mission-oriented innovation policies (Sen, 2013). Addressing market failures and dealing with externalities justified policy action in the further diffusion of science into society. Although this view on science as the main source of innovation was slowly becoming challenged in academic circles, the linear model of innovation remained the dominant narrative and basis for innovation policy for most of the twentieth century (Caraça et al, 2009; Kallerud 2013, Edquist, 2014).

R&D is seen as a major factor behind economic growth by increasing factor productivity. At the same time, innovation is seen as a major contributor to public welfare (Schot and Steinmueller, forthcoming). Kallerud (2010) shows how short-lived periods of social unrest and early signs of environmental damage during the sixties and seventies helped a wider societal agenda to inform innovation policy, making social and environmental objectives dominant over the interest of economic growth. Borras (2007) makes similar observations and characterises this period of S&T policy by a mix of funding basic science with setting some strategic or societal priorities, some of which were explicitly challenge-led (domestic industries such as aviation or automobiles). ADD SOCIAL NEEDS ARGUMENT and quotes from Godin in demand-model inn article.

In terms of our proposed framework, the innovation policy agenda was broader, leaving room for both economic and societal objectives. At the same time, the understanding of innovation remained rather narrow, heavily influenced by a linear view on innovation.

**3.2 Innovation Systems Policy**

In the last decades of the twentieth century, the linear model of innovation lost influence as it was seen as overly simplistic and deterministic in nature (Fagerberg, 2006). Furthermore, the linear model was criticised not only for disappointing direct results but also for failing to deliver any more indirect broader structural support (Ergas, 1986; Chang, 1991). In response to these shortcomings a more systemic or holistic view laid the ground to the Systems of Innovation (SI) approach; a heuristic of different yet complementary ways of framing innovation systems. One way is to conflate the innovation system with national or regional boundaries while another is to delineate the system based on technological, industrial or sectoral characteristics. The different framings are complementary and consider different points of interest in the innovation system, which should be seen as a model of reality designed for analytical purposes. Policy makers started to apply the SI heuristic by identifying different market or system failures to generate a set of policy recommendations (e.g. well-functioning patent laws and IPR’s, good infrastructure, access to finance and a healthy entrepreneurial climate) aimed at improving the activities between the individual components or strengthening the structural composition of the innovation system. Emphasis got shifted from the production to the use of knowledge (Borras, 2003). Furthermore, IS policies have given much more prominence the national context and the role of the state yet recent contributions further open the innovation system to a broad variety of innovative actors such as SME’s, entrepreneurs, users and citizens alike.

While the understanding of innovation became much broader, the policy agenda followed a contrasting path. IS policies mostly shied away from mission-oriented approaches and focussed more on creating good framework conditions for innovation to come about. The idea that the state could ‘pick winners’ was dismissed as something the market could do much better. As a result, there was less room for strategic priorities or national prestige to set the agenda. Kallerud (2010) shows how energy crises and stagflation redefined the economic objectives as primary and dominant again in the mid-seventies and how they remained hegemonic and rather stable for at least three decades.

In terms of our proposed framework the understanding of the innovation process became much broader yet the policy agenda narrowed down by mainly focussing on the economic objectives of competitiveness, growth and jobs.

**3.3 A new discursive space opening up: transformative innovation policy.**

After thirty years of almost uncontested hegemony Kallerud (2013) argues that a broadening of the policy agenda can be noticed since the mid-2000s, spurred on by the advent of new global discourse around Grand Challenges or Green Growth that are opening up new discursive spaces for actors to move into and shape policy outcomes (Wesselink et al, 2013). Scholars have started to question if established second generation IS policy designs are able to adequately cope with nature and complexity of grand challenges. Notwithstanding the diverse stream of research on innovation systems that has emerged over the last decades, IS policy is mainly directed at optimising the innovation ecosystem in order to strengthen its capability to innovate and thereby fulfil economic policy objectives. The ‘normative turn’ that is currently taking place precipitates that innovation policy needs to not only optimise the innovation ecosystem to improve economic competitiveness but also strategically induce directionality and processes of transformative change towards desired societal objectives (Daimer *et al.* 2012).

This is giving rise to what we have labelled a new generation of Transformative Innovation Policy. As figure 1 shows, Transformative innovation policy is partly a return to the past as it encompasses both the technological aspects of grand challenges and corresponding need of science-driven R&D programmes but also includes a more broad-based agenda that aims to accelerate the diffusion of environmentally sound technologies into daily practices and different local contexts. There is a large variety of people and ideas aiming to connect innovation policy with grand challenges. For the sake of simplification, we have attempt to categorise them in three main groups. At the extremes, a rough distinction can be made between those emphasising a narrow techno-scientific and a broad social understanding of innovation. A third group has a socio-technical understanding of innovation presenting something that is not only in between, but actually bridging the two extremes.

Before discussing these different groups, it is important to state here that we are not the first to use the concept ‘transformative innovation policy’ (e.g., Steward, 2008; Scrase et al, 2009), but in most cases TIP is used interchangeably with the concept of system innovation. However, we propose to use the term Transformative Innovation Policy as a much broader umbrella concept. It is this precise point that separates our conceptualisation of transformative innovation policy with that of systems innovation. Rather than equating the two concepts, we argue that transformative innovation policy is a new generation of innovation policy that is layered upon but not fully replacing both earlier generation of S&T and IS policies and of which system innovation is only one part.

*3.3.1 Two extremes: techno-scientific ‘revolutions’ or society-led ‘transformations’*

The group occupying the more narrow part of TIP often speaks in terms of academia and industry-led ‘green revolutions’ (Mazzucato et al, 2015). A distinction can be made between techno-scientific production revolutions with strong government support (Grubb, Hueber, Dechezlepetre, Malerba) or slightly broader techno-economic industrial revolutions by shaping and creating new markets through active government intervention (Mazzucato, Perez). We argue that these approaches ascribe to a narrow understanding of innovation, meaning that they tend to see innovation as the commercialisation of science with academia and industry as leading actors, a strong focus on R&D for new technologies informed by a linear model of innovation and the need to address market failures. They have striking similarities with the old mission-oriented discourse of the past as advocates argue that there is a clear needs of science and technology to become much more challenge-led and explicit in fulfilling a number of important societal goals.

The group occupying the more broad parts of TIP uses terms like society-led ‘transformations’ through new social practices (Avelino et al, 2015), the importance of grassroots innovation for opening up new and different pathways (Smith and Ely, 2015) and the need to engage more explicitly with questions of politics and broader structural social change (Scones, Newell and Leach, 2015). We argue that these approaches ascribe to a very broad understanding of innovation, meaning that they tend to see innovation as an interactive learning process including a broad variety of actors, acknowledging different types of knowledge and different modes of innovation informed by a systemic model of innovation with a strong situated and place-based nature.

It is our understanding that both approaches have much to offer. First of all, there is plenty of evidence for the legitimacy of a more mission-oriented approach for R&D support. This is especially the case with regards to climate change where most GHG-intensive sectors, such as energy and mobility, are characterised by large physical infrastructures and corresponding capital investments that can act as additional barriers to firm entry and innovation. Environmentally sound technologies have to compete on the market with incumbent, often heavily subsidised technologies supported by powerful economic interests (Foray *et al.* 2012). These strong vested interests and sunk costs contribute to the permanence of networks of power, which gives rise to technological momentum that impedes the support of innovation of a more radical nature (Hughes 1987). The impetus and self-reinforcing processes of incumbent technological configurations lead to improvement of prevalent practices and innovation therefore largely progresses incrementally in particular directions in a path dependent manner (Dosi 1982). Grand challenges are increasingly coupled with and aggravated by this structural embeddedness, which is difficult to transform due to these various stabilising lock-in processes leading to path-dependence and entrapment (Unruh 2000, Walker 2000, Grin *et al.* 2010).

Many empirical studies confirm this and legitimise strong public support for R&D. A study by Skea (2014) on R&D spending in the energy sector illustrates shows a big discrepancy between private and public R&D spending in the energy sector, with private money largely going to the oil & gas sector and public money predominantly flowing to the renewables sector. In addition, recent OECD analysis suggests that direct support measures for mission-oriented R&D may be more effective in stimulating R&D than previously thought, particularly for young firms that lack the upfront funds to start an innovative project (Westmore, 2013). Moreover, this justification for mission-oriented R&D targeting new and promising alternatives is empirically supported by a patent analysis showing that climate-change innovations come relatively more often from small and young firms, with close relations to science-institutions (OECD, 2015). As a response, some scholars are calling for a more active role for the state in funding science and technology and actively developing a variety of technological configurations in a diverse array of sectors and funded by both private and public agencies (Mazzucato and Penne 2015). Rather than fixing market failures, the role of the government is to create and shape them (Mazzucato, 2016). This means that the often singular focus on supply-side and technology must be complemented with demand-side approaches led by an entrepreneurial and engaged state that aims to enable transitions that deliver on social needs (OECD, 2015). In sum, given the urgency and temporal dimension of climate change, there are good arguments in favour of more mission-oriented approaches to technological innovation.

However, mission-oriented innovation advocates have been criticised for relying too much on a market-based ideology and relying on techno-scientific promises (Rip et al, 2010). Grand challenges such as climate change is more than just a market failure and the nature and complexity of grand challenges require more than incentivising academia and industry to come up with technological solutions. This group promotes new modes of innovation breaking with prevalent production practices and experience are needed to achieve transitions of societal subsystems systems (Steward 2012). This new innovation paradigm clearly runs counter to the idea of the ‘narrow’ understanding of innovation processes as managed by a single actor or state and hence the technical, economic, and social complexities of grand challenges are if anything more daunting than the ones posed by previous mission-oriented projects (Mowery *et al.* 2010).

Piece about needed institutional changes for private sector to fundamentally address this challenge, based on among Westley et al, avelino et al, etc.

*3.3.2 Observed paradoxes and the appeal of a socio-technical understanding*

As the above section describes, there are arguments for both narrow and broad varieties of transformative innovation policy. It is therefore not our goal to either choose sides or dismiss both. However, we argue that there is a danger of having two narratives that are so far apart and sometimes even contradict each other. We identify two main paradoxes in relation to both actors and knowledge. First of all, too much emphasis on the technological ‘revolutions’ can squeeze out civil actors such as citizens NGO’s and cities. Too much emphasis on the societal ‘transformations’ emphasising the role of bottom-up dynamics of civil society can squeeze out much needed top-down government support and industry action.

Secondly, although a focus on social innovation and other non-technological innovation is crucial and has long been understudied, we also need to acknowledge that we live in a technological age and that any solution to grand challenges such as climate change need to involve revolutionary changes in the technologies and infrastructures created over the last 200 years.

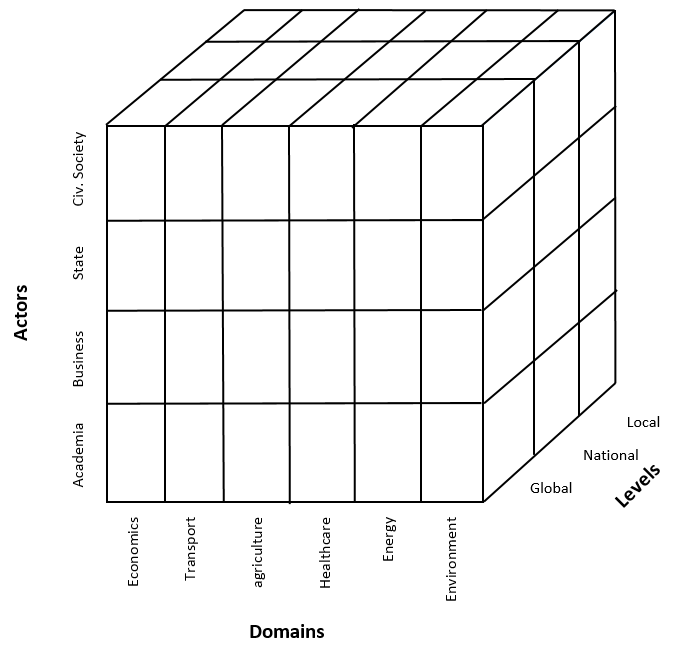
An alternative third group consists of a number of socio-technical scholars. they usually talk about ‘transitions’ of established societal subsystems into environmentally and/or sociably sound ones. They argue that the systemic embeddedness of grand challenges demands a socio-technical approach towards innovation; an interdisciplinary paradigm that has developed over the past decades in response to accumulating societal and environmental problems. Socio-technical systems comprise clusters of interrelated elements including technology, policy, regulation, science, culture, markets, infrastructure etc. (Rip and Kemp 1998). Together these socio-technical configurations fulfil core societal functions such as mobility, energy, housing and health. Coordination and interaction of individual elements create stability and lock socio-technical systems into to particular technological trajectories (Geels 2002). Hence system innovation implies that to change these trajectories both technology and the socio-technical system in which it is produced change through the process of co-evolution and mutual adaptation. System innovation thus indicates the possibility of actively influencing and steering socio-technical systems in desired directions through the horizontal policy approach of mobilising technology, market mechanisms, regulations and social innovations (OECD, 2015). It is argued that systems innovation is not just a technologic, economic or managerial process, but also a political and cultural process that will require not just leadership but also inclusiveness and a shared societal vision to drive it (OECD, 2015). This group therefore gives a much more prominent position to civil society, in addition to academia, industry and government.

We argue that the appeal of the socio-technical model is that it presents something that is not only in between, but actually bridging the two extremes. It offers insights that go beyond focussing on *and* technology *and* social changes by emphasising the social construction of both technologies (e.g. Pinch and Bijker 1987) and entire socio-technical systems driven by co-evolutionary processes between technology and society (Kemp et al 1998). This conceptualisation helps to bridge the previous identified paradoxes by giving room for both an active role for civil society and an active facilitating and enabling state and emphasising both the technological and social nature of innovation. Moreover, the socio-technical understanding of innovation is not simply providing additional policy tools addressing the ‘social side’ of innovation next to a more establishes ‘technological innovation’ policy toolbox. Instead, a socio-technical understanding of innovation also offers concrete policy lessons for conventional innovation policy tools such as cluster policy, R&D support, road mapping, foresight etc. (OECD, 2016).

**4. Policy Practice: multi-level, multi-domain and multi-actor**

Policy makers have shown an increased interest in innovation. For instance, Perren and Sapsed (2012) show that in the UK there has been a tenfold increase in the use of the term in parliamentary debates between the 1960s and the 2000s. We argue that over the last decade, a growing interest in innovation policy can be traced over three dimensions: multi-level, multi-domain and multi-actor. First of all, there has been both a devolution and evolution of innovation policy from the national level to respectively the regional and international level. Examples are for instance cities and regions with their own innovation strategies such as London, Helsinki, Rotterdam, Berlin and many more. At the other side of the equation, we observe a number of initiatives at the supranational level with ever increasing interest and funding at the European level, and recently announced initiatives such as Mission Innovation (Source) and Breakthrough Innovation (Source). Interestingly, there are also initiatives that combine the two with the Global Compact and the Covenant of Mayors who recently merged to become the Global Covenent, representing over 7000 cities that together want to address climate change and have a big emphasis on innovation (source).

Secondly, innovation policy is becoming multi-domain, explicitly entering domains such as agriculture, health and energy. This is extensively documented by the OECD (source) and the European Commission (EC, 2002) and can also be observed at the EU policy level were Research and Innovation is a topic no longer solely addressed by its respective Directorate General, with independent strategies being formulated by other DG’s such as energy (source) and mobility (source). Thirdly, innovation policy is becoming multi-actor being a central objective to academia, business and government and more recently many NGO’s joining the club formulating their own innovation strategies such as Oxfam, WWF, Friends of the Earth



**4.1 International initiatives on the intersection of climate action and innovation on a global scale**

The empirical part of this paper focuses on a number of above mentioned recently announced initiatives on the intersection of climate action and innovation policy. In figure x, these are initiatives consisting any type of actors operating at the international level and covering the domains of energy and/or environment. The reason we focus on these initiatives is because we ascribe to the idea that the nature and complexity of climate change demands a coordinated and global policy response to accelerate the pace and scale of innovation in environmentally sound technologies, services and practices.

Nonetheless, we observe a paradox in the sense that the broad socio-technical model of innovation advocated in the first part of this paper is usually conceptualised in a situated or place-based setting and is therefore intuitively difficult to combine with the emerging international agenda of these new initiatives. We argue that this paradox needs to be addressed as we observe that many of the more prominent international initiatives show a clear ‘techno-scientific reflex’ falling back on purely STI modes of innovation with traditional actors from academia and industry. We argue that insights from economic geography and Actor-Network-Theory show that a networked model of innovation can bridge the observed paradox and help guide international initiatives that wish to take on a broader understanding of innovation. Due to its high profile, special attention is given to ‘Mission Innovation’, an intergovernmental cooperation between twenty different countries announced at COP21 in November 2015.

**4.2 A socio-technical understanding of the transfer and diffusion of knowledge**

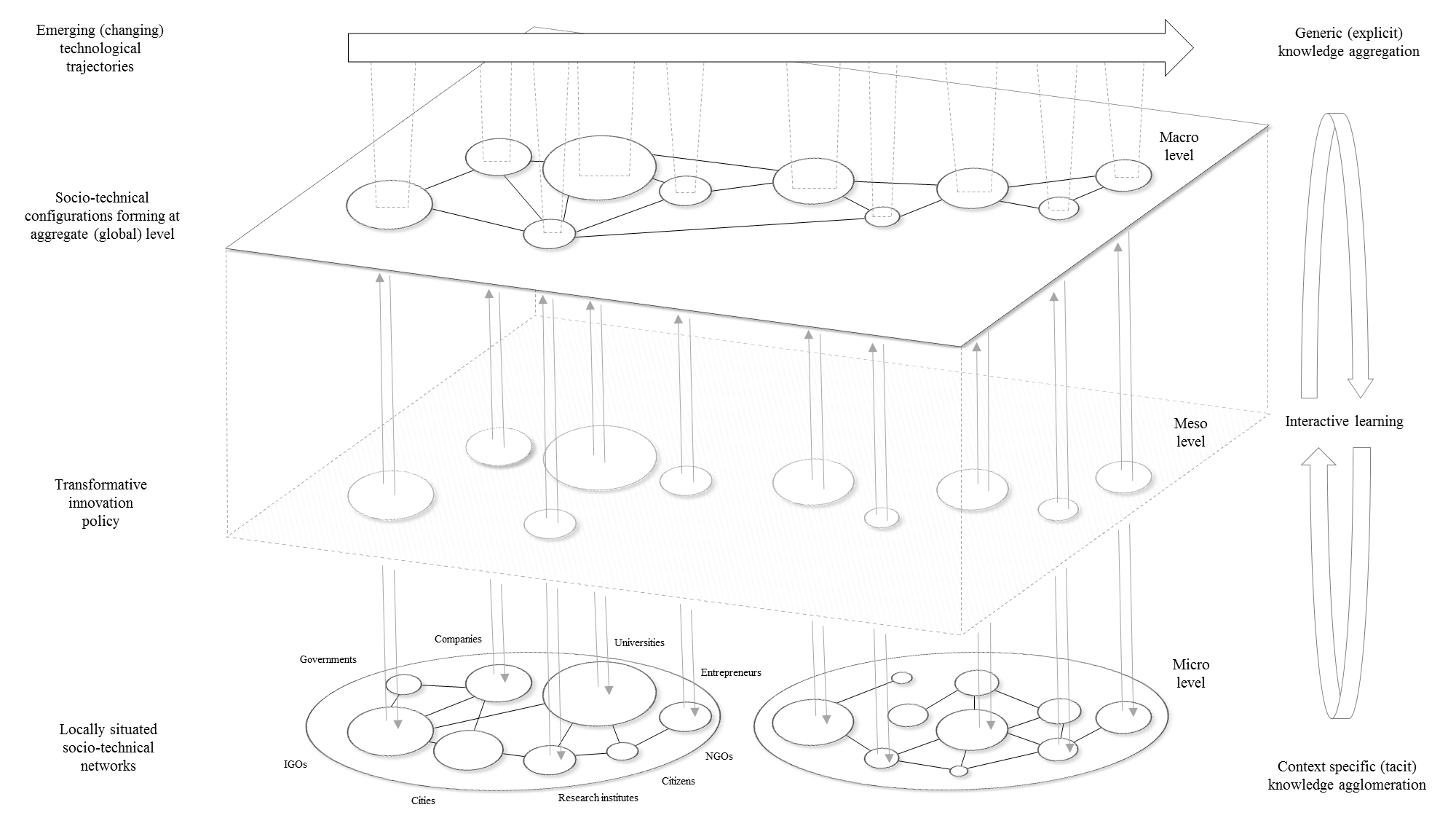
One of the main reasons why there is an observed paradox between a broad-based model of innovation and international cooperation is the perceived stickiness of tacit knowledge that, in contrast to codified knowledge, is difficult to communicate by means of writing it down or verbalising it. It is often argued that it is relatively simpler to diffuse tacit knowledge over short geographical distances while the positive externalities become less intense and often costlier the larger the distance (Jaffe et al. 1993). Geographical proximity likewise influences the diffusion of more explicit forms of knowledge as interpretation and assimilation of it often requires the use of tacit knowledge (Jensen et al. 2007). As a result, it is often suggested that innovation and interactive learning requires co-location due to this tacit nature. Hence knowledge is generally understood to be geographically bounded, and spatial agglomeration of actors around particular knowledge bases stimulates innovative activity.

However, this traditional view on knowledge diffusion can be challenged and recent developments suggest that geographical proximity may not be a necessary nor sufficient condition for innovation as other forms of cognitive, organisational, social and institutional proximity may substitute to solve problems of coordination and knowledge asymmetries (Boschma 2005). Knowledge can also be understood as relational ties in actor-networks (e.g. Latour 1987, Callon 1991); a dynamic that is recursively produced and re-produced through relatively stable heterogeneous configurations in networks consisting of human (social) and nonhuman (technical) elements and working linkages We follow this line of argument and conceptualise socio-technical space as relational and thereby to be socially constructed rather than geographical.

A socio-technical conceptualisation of space changes not only the global geography of innovation but also has important implications for international policy initiatives. It runs counter to much of the established literature on clusters and innovation systems, which often set spatial boundaries around the agglomeration of knowledge at different geographical levels. Yet the limitation of innovation studies to particular spatial dimensions seems less and less appropriate, and scholars have started to engage with this new reality and pay attention to how innovation processes work between interrelated spatial scales (Coenen et al. 2012). The recent literature on geography of sustainability transitions is particularly attentive to the notion of space of innovation and illustrate the impact of spatially dispersed yet interconnected innovative activities (Binz et al. 2014); an intensifying dynamic, which has led to a notable increase in the outsourcing and offshoring in R&D activities and rapid growth in highly innovative industries in seemingly unrelated places (Gosens et al. 2015, Chaminade et al. 2015). Analytical focus therefore shifts from the geographical proximity of knowledge to its embeddedness in different socio-technical settings, and how constellations at more aggregate levels connect actors to new and different forms of knowledge.

The focus on a more complex notion of relational space, however, does not make geographical space obsolete. This is because a socio-technical understanding of innovation implies that technological knowledge is influenced by actors whose techniques, skills, methods and processes tend to derive from local experience, habits and established practices. In other words, the agglomeration of technological knowledge is highly context specific and therefore often localised. Consequently, for it to work under spatially different socio-technical settings, it has to be ‘transformed’ into more explicit forms, which are sufficiently generic, abstract, and context free. This dynamic has been described as the local-global activity of ‘dis-embedding’ and ‘re-embedding’ of knowledge; an aggregation process through which tacit and context specific knowledge is transformed into more generic forms, which can be applied and made to work under different socio-technical settings (Geels and Deuten 2006). Hence, in their paper, Geels and Deuten argue that “aggregation activities by intermediary actors do not revolve around finding technological solutions of local, specific problems, but rather around the creation, maintenance and distribution of generic, abstracted knowledge” (ibid 2006:267).

We base ourselves on this understanding but argue that it is not the aggregation activities of particular intermediary actors that transform or dis-embed knowledge but rather the relational space created through the formation of new socio-technical configurations at more aggregate levels that allow a more diverse set of actors to connect, exchange and combine new and different forms of knowledge. The importance of ‘intermediates’ therefore relates more to the creation of relational space that allow particular actors to function as nodes in the formation of more aggregate socio-technical configurations to improve the relative ease with which knowledge is transferred and diffused. A socio-technical understanding of innovation would therefore interpret the international policy initiatives as attempts to create relational ties to strengthen international cooperation and improve connectivity between locally embedded actors with the expectation that interaction, exchange and combination of new and different forms of knowledge will stimulate knowledge development and accelerate innovation in environmentally sound technologies. The formation of socio-technical networks at more aggregate levels can be visually illustrated as done in Figure 2.

Scholars have through a number of recent studies, at least implicitly, demonstrated the dynamics outlined in our framework. Binz et al. (2014), for instance, propose a relational and networked view on global knowledge production in their case on membrane bioreactor technology and clearly show how national subsystems are embedded differently in this setup. Similarly, Gosens et al. (2015) explore how transnational dimensions influence innovation processes in cleantech industries in emerging economies and conclude that while spatial borders do not confine technology, the influence of locally situated actors are critical to the global formation of technological innovation systems. Sengers and Raven (2015) study the stability and prospects for change in socio-technical networks in a developing country context and explain how transnational networks influence strategic niche management processes in their case on bus rapid transit systems while Wieczorek et al. (2015) demonstrate the prevalence of transnational linkages in transitions oriented solar PV experiments in India. Moreover, an emerging literature on global innovation networks is attentive to the networked organisation of innovation activities (primarily from a firm-level perspective) and how knowledge flows transcend local and national boundaries and emerge at the global level (Liu et al. 2013, Chaminade and Plechero 2014, Herstad et al. 2014, Aslesen et al. 2016).

**4.3 Challenges for dis-embedding and re-embedding processes**

A social-technical understanding of innovation has implications for policy and two observations related to the transfer and diffusion of knowledge seem worth making. The first observation relates to the process of dis-embedding towards more aggregate socio-technical configurations. The second deals with re-embedding to more situated socio-technical configurations.

Firstly, there is a duality of structure between the socio (human) and the technical (nonhuman) that is recursively generated in socio-technical networks; a duality, which does not work deterministically but interacts with and is affected by agency (Giddens 1984). The opportunity of influencing and actively steering socio-technical networks by coordinating processes of structural change through which entire societal subsystems transition to more sustainable modes of consumption and production is therefore often suggested (Markard et al. 2012). It seems plausible that policy initiatives that support the formation of more aggregate socio-technical configurations, connecting a broader and more diverse group of locally situated actors through the transfer of different forms of knowledge may well contribute to innovation. The development of shared routines and cognitive frameworks of engineers and designers and other forms of generic knowledge aggregation clearly guide organisational activity especially with regard to innovation (Nelson and Winter 1977). It is likely that aggregate socio-technical configurations might influence the trajectories of technological regimes whose boundaries create stability and impetus by providing a sense of direction for incremental technological development (Dosi 1982). In other words, the formation of more aggregate socio-technical configurations through the creation of relation space (the raison d'être of international policy initiatives) may result in shaping the trajectories of technology, or ‘pathways’ that we deem to be sustainable. Stirling (2015) shows that the process of structuration as described above makes it possible to either open-up or close done a variety of pathways towards sustainability. It is for this reason that he argues for policy initiatives that not only show direction (e.g. environmental sound technologies, services and practices) but also allow for diversity through an open democratic process (Stirling, 2007). Smith and Ely (2014) show how this framework can be especially relevant in the local-global dynamics of translating ‘grassroots’ solutions to more aggregated global level

Secondly, the purpose of international policy initiatives, such as Mission Innovation, is to accelerate the pace and scale of innovation in environmentally sound technologies, services or practices. It is reasonable to assume that more aggregate socio-technical configurations will result in the development of new knowledge for innovation in environmentally sound technologies but these have to diffused under spatially different local socio-technical settings through a process of re-embedding. The social, cultural and institutional embeddedness of knowledge implies that technological knowledge almost always has to be modified and adapted to local socio-technical settings (Rip and Kemp 1998). Yet prevalent technological trajectories reinforce and make socio-technical networks dynamically stable through various lock-in effects resulting, for instance, from improvements in price and performance (Arthur 1989), increasing returns of adoption (David 1985), embedded institutional commitments (Walker 2000) and techno-institutional complexes (Unruh 2000). These is in turn may be de-stabilised from bottlenecks (Rosenberg 1976), reverse salients (Hughes 1994) and diminishing returns of technology (Freeman and Perez 1988). The combined influence of rules and activities imposes a sense of logic and direction, which gives rise to dynamic stability and technological momentum in socio-technical networks. This inhibits innovation in heavily entrenched systems, where change tends to be incremental and path dependant and the diffusion of technological knowledge, particularly of a more radical nature, can therefore not be considered a seamless process (Hughes 1987). Furthermore, the re-embedding of technological knowledge in local socio-technical networks does not happen automatically but requires particular enabling conditions and a commitment to active learning; a dynamic, which combined can be referred to as absorptive capacity (Cohen and Levinthal 1990). Earlier studies often make reference to ‘global technology opportunity sets’ to which all actors have equal access (e.g. Carlsson et al. 2002) yet recent evidence on the spatiality of innovation processes reveals a picture of differentiated access that are unevenly distributed across space (Berkhout et al. 2009, Raven et al. 2012, Weber and Rohracher 2012, Hansen and Nygaard 2013).

In short, actors differ in their ability to not only access and tap into the global flow of knowledge but also to make use of it for innovative activities. It therefore seems that the mutual benefits of involvement in different international policy initiatives is conditioned by different levels of absorptive capacities of actors and the relative entrenchment of socio-technical networks. The relative ease with which knowledge can be transferred to and from locally situated socio-technical settings goes a long way of explaining why innovation activities are not uniformly or randomly distributed globally despite the potential existence of ubiquitous ‘global technological opportunity set’. Consequently, the formation of aggregate socio-technical configurations should be characterised as uneven and dynamically evolving structures to which local situated actors with different relational positions and absorptive capacities have differential access at different points in time.

This means that aggregated socio-technical configurations have to be re-embedded again. As a result, a disaggregation process to a partly localised context must take place, resulting in a broad diversity of locally embedded socio-technical configurations (e.g. not one but thousands of energy transitions (Sarrica et al, 2016)). This again has policy implications for those aiming to direct these processes (e.g. speed up the energy transition). We re-emphasis Strlings argument about the fact that directionality needs to go together with diversity and democratisation and argue that not doing so has its dangers. Research on the formation of socio-technical regimes (Fuenfschilling and Truffer, 2014) show how aggregate socio-technical networks create dominant global regimes in for instance water infrastructures or smart city solutions that basically copy/paste their dominant configuration, seriously limiting the (arguably much needed) diversity of context-specific solutions.

Concluding: diversity is essential in both processes of disembedding and re-embedding and should be an integral part of any international initiatives that wants to embrace a broader socio-technical understanding of innovation.

**Annex/Scraps**

This poses interesting about questions about the networked arrangements of actors in aggregate socio-technical configurations and if some constellations are better at producing and diffusing innovation than others. The innovation literature has paid great attention to the global interactions for innovation and their possible effects on actors and contexts (e.g. Bathelt et al. 2004). In their seminal paper, Archibugi and Michie (1995) carefully consider the different modes of interactions in the globalisation of innovation and reason that globalisation cannot be considered a single phenomenon. This argument is further developed in Archibugi and Michie (1999), where a taxonomy is presented based on three categories: ‘international exploitations of technology’, ‘global generation of innovations’ and ‘global technological collaborations’. The categories resemble types of global interaction comprising different groups of actors, which emerged in three successive stages even though the second and third coupled rather than replaced the first one. The first category (international exploitation of technology) refers to innovators attempt to obtain economics advantage from the diffusion of innovation in markets other than the internal one. The second category includes innovation conceived on a global scale from the moment they are generated. This interaction requires particular organisational and administrative skills and a specific infrastructure and for this reason Archibugi and Michie delimit the networked arrangements of multinational enterprises in this category. Finally, the third category (global technological collaborations) refers to the ability to develop innovation involving collaboration a broad set of actors i.e. firms, universities, research agencies etc. Archibugi and Michie discusses the role of public policy for each category, exploitation, generation and collaboration, and argue that although the categories they partly overlap they should be separated and treated differently.

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