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Austria 2025:

A New Strategic Innovation Policy Framework

Addressing Structural Change and Upgrading

Jürgen Janger, Agnes Kügler, Andreas Reinstaller, Peter Reschenhofer, Fabian Unterlass

Research assistance: Kathrin Hofmann, Anna Strauss

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Abstract

Innovation is increasingly seen as the dominant policy to address both economic and societal objectives. As a survey of the innovation policy literature in this paper shows, performance goals for innovation efforts are usually very general, framed as increasing the rate of innovation activities or as changing the direction of innovation activities towards specific societal goals. We argue that there is a middle layer missing in the hierarchy of performance goals, a layer which connects bundles of individual policies and the overarching country-wide innovation performance. Recent research suggests that the economic effects of innovation must be reflected at the sectoral level in either structural change towards knowledge-intensive sectors or upgrading within sectors towards more knowledge-intensive segments. We propose to investigate whether this way of measuring innovation outcomes – which we call the innovation frontier – is a suitable focussing device for innovation policy-making at the national or regional level. The paper outlines the conceptual basis for further more empirically oriented research.

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1. Introduction

Innovation is increasingly seen as the dominant policy to address both economic and societal objectives. Not least due to a burgeoning literature on various rationales for and effects of innovation policies, the range of policies available to policy makers has become so great that an own strand of the innovation policy literature is devoted to innovation policy mixes. The pursuit of the combination of policies most effectively addressing a country's specific innovation challenges is becoming ever more complex. As a survey of the innovation policy literature in this paper shows, performance goals for innovation efforts are usually very general, framed as i) increasing the rate of innovation activities (boost either the generation, diffusion or use of innovations, or productivity) or ii) as changing the direction of innovation activities towards specific societal goals. Foray (2009) notes that goals of overarching technology policy are usually not discussed. By contrast, individual policy goals are usually not framed in economic or outcome terms, but as direct results or outputs of these policies, e.g. more R&D spending by firms is a goal of policies subsidising firm R&D efforts.

We argue that there is a middle layer missing in the hierarchy of performance goals, a layer which connects bundles of individual policies and the overarching country-wide innovation or productivity performance. Recent research suggests that the economic effects of innovation, or innovation outcomes, must be reflected at the sectoral level in either structural change towards knowledge-intensive sectors or upgrading within sectors towards more knowledge-intensive segments within these same sectors (Janger et al., 2017). We propose to investigate whether this way of measuring innovation outcomes – which we call the innovation frontier (Janger et al., 2016) – is a suitable focusing device for innovation policy-making at the national or regional level.

Focusing policies on either structural change towards more knowledge-intensive sectors or within-sector upgrading could present such a middle layer of performance goals which provides new directionality in efforts to improve overall innovation performance or the rate of innovative activity.[1] This is also relevant for achieving societal goals such as fighting climate change, as the rate of innovative activity in a certain direction determines the speed with which societal goals can be reached. Structural change refers in this paper to growing shares of knowledge-intensive sectors in the overall economy, of either existing firms diversifying their capabilities to enter new growth areas, or new firms exploiting new market opportunities. It is understood here as a specific meso-level concept of changing sectoral shares in the direction of more knowledge intensity, rather than as a generic concept neutrally denoting changing compositions of firms or sectors. So far, measurement and comparison of innovation outcomes at the country level has focused on shares of knowledge-intensive sectors in the economy or goods and services in exports (Godin, 2004); at the policy level, this has given rise to "high-tech"-strategies, or efforts to increase the share of such sectors,

[1] On the directionality point, see also Edler and Nowotny (2015).

because of the presumed higher growth effects of such sectors, either directly through their growth or through higher knowledge spillovers to other sectors.

This masks a potentially much more frequent case of innovation outcomes, upgrading (see Janger et al., 2017). In advanced countries, upgrading refers to constant efforts by firms to stay ahead of the game in their established markets, using innovation activities to deepen their capabilities ("getting better at what they do") and gain competitive advantages in cost or product quality, without changing the overall composition of economic activities. Facing growing competition from emerging countries, they need to climb the "quality ladder" of their industries to defend market shares and gain growth opportunities in hitherto untapped geographic markets. Upgrading can also be the result of new firms entering existing markets and proposing disruptive innovations, which are based on new capabilities but lead to products addressing the same needs as before (e.g. see taxis and UBER). In transition or emerging countries, upgrading can be seen as catching-up to the innovation frontier of specific sectors. While upgrading has always been there as a competitive strategy of firms, it was so far mostly ignored in advanced countries as an explicit performance goal for innovation policies, not least due to the absence of its measurement until recently.

Novel empirical indicators of upgrading and change towards more knowledge-intensive sectors show that some countries do well in the "change"-dimension of innovation outcomes, while not doing so well in the upgrading dimension (Janger et al., 2017). These are sometimes emerging countries which have managed to join the global value chains of multinational firms in knowledge-intensive industries. They are more likely to be in the less knowledge-intensive segment of such industries, featuring assembly of final products rather than innovation activities. Examples are Hungary or Slovakia, but also countries such as Ireland, with large shares of sectors classified as knowledge-intensive, but relatively little own R&D or innovation activities taking place in these sectors. But also advanced countries can have problems with upgrading, as evidenced by the problems of the US in certain sectors where they once enjoyed the lead (Autor et al., 2016; Berger and MIT Task Force on Production in the Innovation Economy, 2013; Rosenberg and Steinmueller, 1988). Nokia in Finland is a classic case, where a failure in "upgrading" has significantly reduced the share of knowledge-intensive sectors.

Other countries do relatively well in the upgrading dimension, but are less good in the "change"-dimension, i.e. featuring relatively low shares of knowledge-intensive sectors. These are usually more advanced countries with accumulated capabilities in less knowledge-intensive sectors, where they occupy the top end of the quality ladder. Examples are countries such as Austria, which is highly productive in industries such as metal, wood and machinery (Peneder, 1999), or Italy, which features high quality in labour-intensive industries (see Janger et al., 2011). For various reasons, they are struggling however to enter new, more knowledge-intensive industries. For these two groups of countries, a change-upgrading-focusing device could be potentially most helpful to provide directionality for innovation policies aimed at increasing the rate of innovation activities. Countries doing either well or badly in both dimensions can gain less in terms of policy prioritisation from the adoption of this approach, but the approach is still useful as an analytic guide for performance and policy analysis, as international competition is growing, global value chains spread and the search for new sources of growth amid fears of "secular stagnation" becomes more intense.

In this paper, we first give an overview of current innovation policy approaches to show that changing the sectoral composition of activities towards more knowledge-intensive activities and within-sector upgrading are absent from the performance goals of innovation policies, potentially neglecting an important focusing device for effective policy bundles. We then relate the concept of change and upgrading to the existing literature and discuss which policies are more likely to address change vs. upgrading. We then proceed to our own empirical analysis of the drivers of change vs upgrading. We conclude with an outlook on potential further research, which should be focused on more closely identifying which policies contribute to either change towards a higher share of knowledge-intensive activities or upgrading.

2. Performance goals in innovation policy approaches: a review

In this section, we briefly review innovation policy surveys to show the various types of innovation policies, e.g. by type of rationale or by type of instrument, and the corresponding goals of these policies to illustrate the overwhelming complexity of innovation policy today, given the large variety of government action seen as potentially beneficial for innovation. We conclude that analysing policies with respect to their effect on structural change vs. upgrading could be a potentially effective focusing device.

For the purpose of this article we define innovation broadly, including innovation in- and outputs as well as outcomes and impacts, or following Janger et al. (2016), innovation refers not just to the generation of new knowledge, technologies, products or processes, but also to their diffusion and use, as this mostly creates economic impact, rather than the first introduction of a novelty. Innovation policy is often conceptualised as the largest policy area, with science and technology policy more specifically addressing the conditions for scientific knowledge production (usually basic R&D, mostly in universities and government labs) and technology policy devoted to fostering strategic technologies or sectors, or more generally the application of scientific knowledge to practical uses. Innovation policy also includes efforts to foster non-technological innovation and is not just concerned with technological knowledge creation, but also with value creation based on new knowledge (see Lundvall and Borrás, 2005; Janger et al., 2016). Often, the terms technology policy and innovation policy are used interchangeably, however. In this paper, we follow Janger et al. (2016) who distinguish between the capability to contribute to the scientific, technological and the innovation frontier. Science policy would aim at strengthening scientific knowledge production capabilities, as measured e.g. by quantity and quality of publications; technology policy's goal is to boost technological knowledge production capabilities, manifesting themselves in the production of tacit and codified technological knowledge or inventions, leading to the market introduction of innovations.[2] Innovation policy needs science and technology policy, but aims in addition at turning knowledge produced into tangible economic benefits.

Innovation policy is then about what governments or other actors can do to foster innovative capability in firms or other organisations and actors (such as users), or to foster the generation, diffusion and use of innovations with a view to reaching specific objectives. It is usually based on a more or less explicit model of the innovation process in firms, on the inputs firms need for successful innovation activities, or on the external incentives. E.g., in a linear model of innovation, discoveries of basic science are used for inventions, which are commercialised into products or services and if successful, diffuse throughout the economy. In this model, commercialisation of new knowledge is not of great concern, as it is supposed

[2] Steinmueller, 2010 distinguishes scientific from technological knowledge by its mode of production and by its openness: scientific knowledge is knowledge produced for open disclosure with the aim of achieving recognition as the originator (scientific priority) while technological knowledge is produced with the aim of capturing some form of exclusive rights to its use (with exclusivity protected by patents or other means, such as secrecy).

to happen through the market anyway.[3] It is the exception nowadays in how innovation is seen to happen in firms (Fagerberg, 2016) but remains useful (Balconi et al., 2010). More recent models such as the chain link model (Kline and Rosenberg, 1986) acknowledge that ideas for innovations do often not come from basic science, but are generated within the firm, or by suppliers or customers/users, with multiple feedback loops between research, invention, production and commercialisation, acknowledging that commercialisation can be both a barrier and a source of successful innovations. Different models of the innovation process, together with different theories of innovation, give different accounts of what can go wrong in the innovation process and where public intervention could be beneficial; where firms can't do it on their own, or not as good without some form of support, or need to be incentivised to adopt socially beneficial behaviour. There are also non-firm centred innovation models, e.g. systemic innovation approaches deemed necessary for a transition to sustainability, where deliberation processes with civil society play a much larger role (Schot and Steinmueller, 2010). In this article, we focus on firm-centred innovation policy.

In the literature, systematisation of the various innovation policies is done by theory and rationale (what is the underlying problem, why public action is superior to laissez-faire), by type of policy (affecting important ingredients of the innovation process) or by innovation process or activity.

2.1 Innovation policies by rationale

In terms of theory or rationale for (research) innovation policy, research has started out with a "narrow" rationale for public intervention, based on the Arrow-Nelson paradigm (Arrow, 1962; Nelson, 1959) that underinvestment in R&D is a consequence of a lack of appropriability of the returns to R&D spending, as knowledge is non-rivalrous in use and can be used free of charge by competitors, which undermines incentives for innovation efforts. R&D subsidies for research far from commercialization[4] and protection of intellectual property are hence two policies which allow for improving social welfare by influencing the rate and direction of inventive activity (or technological change), which were named as the two main outcomes of innovation efforts (and hence goals for innovation policy) in a famous NBER conference (Universities--National Bureau Committee for Economic Research and Social Science Research Council (U.S.), 1962). To increase the rate of inventive activity, increasing the returns to inventive efforts was the basic recipe. Otherwise, firms know what is best for them.

A much wider scope of public action is potentially beneficial for innovation building on the insights of evolutionary economics and the theory of national innovation systems (see, for surveys, (Fagerberg, 2016; Lundvall and Borrás, 2005; Malerba, 2009; Steinmueller, 2009). An

[3] On this point, see Schot and Steinmueller, 2016.

[4] The further away from application, or the more creation of basic knowledge is involved, the more externalities or potential spillovers are to be expected which are not appropriable by the firm, whereas the closer to market, the higher the chances for a firm to fully appropriate the returns on research and innovation efforts, and the less spillovers, or knowledge which could be applied in different production processes, will result.

evolutionary view of technological change is based on cumulative, path-dependent technological advance in uncertain environments by firms which vary widely in capabilities and progress by learning and making mistakes, rather than choosing innovation options based on full information. Opportunities for technological advance do not just fall from the sky, but are specific to technologies. In such a setting, the market failures from the Arrow-Nelson paradigm are complemented by evolutionary failures (Malerba, 2009). These include

- a failure in the generation of technological opportunity conditions, affecting R&D by established firms and the entry of new firms into an industry, with possible remedies being supporting basic research and a common knowledge infrastructure;
- a failure in learning by firms and in accumulation of capabilities, e.g. insufficient R&D or human capital to initiate learning and capability building, or problems with the diffusion of technical knowledge, to be remedied by education and skills policies, including training of researchers by universities, as well as industry-specific R&D support and diffusion policies
- evolutionary lock-ins and trade-offs, e.g. when firms within their search efforts trade-off exploitation of technologies they know against exploration of new technological opportunities; firms can be victims of their success, remaining in existing technologies while disregarding alternatives (see, e.g., stories of new entrants which disrupt business models of existing firms). This also can be framed in terms of a tension between variety creation and selection in industrial dynamics. Possible remedies include contact with basic research in universities (developing networks of knowledge and opening new windows on technologies), upgrading human capital of researchers and using public procurement to incentivize firms to start learning how to create and use new technologies, creating conditions for increasing variety through the entry of new firms, as well as open standards and norms.

Innovation performance becomes more broadly defined, from the rate and direction of inventive activity to the implementation and diffusion of innovations.

The theory of national innovation systems builds on these insights by linking learning, competencies and heterogeneity of actors at the micro-level (and how this affects innovation) to how interactions and linkages among various actors and institutions affect the creation, commercialisation and diffusion of knowledge, or the performance of innovation systems at the macro-level.[5] Basically, firms can't produce all the inputs or ideas they need for innovation on their own, they need to cooperate with external actors, such as suppliers or customers, or knowledge-producing organisations such as universities. Institutions, such as basic trust in society, hence also affect innovation as trust facilitates cooperation for

[5] See Soete et al., 2010, p.1163: "The central idea in modern innovation systems theory is the notion that what appears as innovation at the aggregate level is in fact the result of an interactive process that involves many actors at the micro level, and that next to market forces many of these interactions are governed by non-market institutions. Because the efficiency of this process observed at the macro level depends on the behaviour of individual actors, and the institutions that govern their interaction, coordination problems arise."

uncertain innovation activities which cannot be fully regulated or codified by contracts. System or coordination failures can emerge when

- key elements or nodes in the innovation system are missing, preventing dynamic complementarities or keeping interactions at suboptimally low levels. Possible policies include enhancing cooperation through creating bridging organizations, or enhancing capabilities of actors through education and basic research, or mobility of researchers to exchange tacit knowledge.
- Existing innovation systems can't change or new ones don't emerge, e.g. for specific technologies; this can be addressed through standard setting, but it is difficult to foster the emergence of new systems through top down central coordination

As a consequence many policy fields, not just those with the explicit intent to affect innovation, become relevant when trying to boost innovation performance, and policies need to take into account national, regional or sectoral specificities, as innovation systems develop over time; in fact, it is partly the observation of differences in innovation performance and systems between countries which gave rise to the theory of NIS (see e.g., (Nelson, 1993). At the performance level however, goals remain similar with the creation and use of innovations.

A different range of rationales for innovation policies can be derived from taking into account spatial dimensions of innovation processes (see Steinmueller, 2009). The rate of inventive activity is affected by differences in the spatial density of firms and other knowledge institutions, e.g. innovation processes are spatially mediated through the (growing) importance of tacit knowledge which can usually only be transmitted through face-to-face interaction; competition by locally present firms contributes to the diffusion of knowledge, to adoption of innovations developed by other firms (imitation of drivers of competitive advantage). There is a huge literature on the effects of clusters and agglomerations on innovation, and also on the co-location of industry and research institutions (Feldman and Kogler, 2010; Audretsch et al., 2015). Innovation policies include fostering cluster formation, building top research institutions to attract researchers, but also tax incentives for firms relocating to specific places.

In addition Steinmueller (2009) also mentions specific rationales such as infant industry development, problems with the development of demand for innovation and imperfect capital markets. In all of these accounts of innovation policies however, the goals for policy action are usually the same at a general level: to increase the innovation performance of a country or a national innovation system is tantamount to increasing the rate of innovation activities, or to increasing the creation of knowledge and inventions, commercialisation and use/diffusion of innovations, with the ultimate economic benefit of increased productivity and employment and/or competitiveness of firms.

Schot and Steinmueller (2016) summarise these accounts as embedded in a view of the world where firms and hence countries compete between each other based on R&D efforts, where in a first framing technology flows freely across borders (the Arrow-Nelson paradigm) and in a second framing technology does not flow so freely and where for successful innovation-based competition more is necessary than just subsidising R&D in universities and firms, i.e. effective (national) innovation systems. They maintain that a third framing, transformative innovation policy is necessary for a transition of economies and societies towards economic and social sustainability; this is emerging research however.

2.2 Innovation policies by type of policy

Another effort at synthesizing the huge amount of innovation policies proceeds simply by type of policy, or instrument used to foster the rate of innovation; the discussion of the rationale for these policies plays of course a role, but the classification criterion is by policy, not by rationale, which may overlap for various policy instruments. Authors such as Lundvall and Bórras (2005) differentiate by policy domain, science, technology, and innovation, as outlined above. Other authors explicitly go to the instrument level. E.g., Steinmueller (2010) proposes 4 themes and 12 designs to influence the rate and direction of technological change, ultimately with the goal of influencing productivity, among which:

- Supply-side designs support the creation of knowledge and the development of innovations by the innovator, i.e. following the approach that innovations or new technologies are pushed by development efforts onto the market, by ideas generated by the innovator, or in cooperation with research institutions or suppliers. They work on the cost side of innovation and reflect partly the linear model of innovation where "the "upstream" supply is meant to stimulate the more market-led downstream processes of innovation commercialization" (Steinmueller, 2010, p. 1192). Variants include
    - horizontal subsidies: e.g. R&D tax credits, or direct sector-neutral R&D subsidies
    - thematic funding, i.e. non-neutral R&D subsidies for specific sectors or technologies,
    - signalling strategies, in the form of e.g. demonstration projects to show that technologies are worth developing; and
    - financial policies, such as the promotion of venture capital availability
- Designs for the supply of complementary factors to reduce the costs of inputs needed for innovation or large-scale commercialisation, preventing any bottlenecks which may arise in innovation processes, e.g. as in
    - labour supply for innovation activities
    - Technology acquisition policies e.g. assisting with technology licensing contracts
- Demand side designs are meant to "pull" innovations onto the market, acting from the side of those who buy or request innovations, increasing the expected profitability of innovations (see e.g., Kleinknecht and Verspagen, 1990) or reducing the uncertainty about market demand for innovations, and include
    - adoption subsidies for users (e.g. for the use of alternative energy)

    - Information diffusion policies
- Institutional change designs reflect the more NIS-style policies of making sure that networks of actors can effectively coordinate on the development or use of knowledge (so that in principle both cost and demand side issues can be addressed); if dysfunctions in the existing systems are perceived, e.g. due to observation of international comparative performance, several options are possible:
    - Assigning new missions to public institutions is viewed by Steinmueller (2010) as a common response to dysfunction in a system. E.g., developing new technologies could be assigned as a mission to universities or public research laboratory
    - Creating new institutions to address the problem of missing links, e.g. in SME-dominated markets, research intermediaries can provide research services and information dissemination to compensate for the size disadvantages of small firms in building technological know-how, due to indivisibilities in R&D. Germany's Fraunhofer -Gesellschaft is an often cited example.

Edler et al. (2016) survey the available evidence on innovation policy impact, where innovation policy is defined as public intervention to support the generation and diffusion of new products, processes or services, and includes all instruments that directly affect innovation or that indirectly have strong effects on it while addressing other policy purposes; they see two broad classes of innovation policies, supply- (supporting innovation generation) and demand-side policies (influencing those that request, buy or apply innovations) innovation policies.

- Among supply (innovation cost reducing) policies, there are
    - fiscal measures and direct R&D subsidies
    - access to finance policies (venture capital, credit guarantee schemes)
    - policies building skills, such as skills development, labour legislation, immigration schemes and access to expertise (technical services and advice (innovation management, IP management…)
    - cluster policies, network policies and support for R&D cooperation (including hence the discussed spatial dimension of policies)
- Among demand (innovation profitability increasing) policies, there are
    - Measures using public procurement (forward commitment, procurer networks, awareness measures, procurer training, bundling of demand)
    - instruments to support private demand (command-and-control regulation and price-based instruments)
    - Acting on both supply and demand is pre-commercial procurement (support to the innovation generator, with grants specifying a public need and intent to subsequently buy)
- Apart from supply and demand, framework conditions matter, such as product or labour market regulation and standards

- Policy dialogue through foresight builds strategic intelligence
- All of these policies address 7 innovation policy goals
    - increase R&D investment
    - augment skills
    - strengthening system-wide capabilities and exploiting complementarities
    - enhancing innovation demand
    - improving frameworks for innovation, including regulation and standards
    - facilitating exchange and dialogue about innovation

As this analysis of innovation policy by policy type shows, the overall goal of innovation policy stays the same, in the form of increasing innovation performance, with an increasing rate of innovation ultimately leading to higher productivity as an economic outcome, while individual policies have their own goals, which are not innovation outcome goals, but refer to the output of the policies themselves, such as higher R&D expenditure or more skills. A different take on innovation policy is provided by the literature on technological innovation systems, which analyses the functional dynamics of TIS by "processes" or activities (see Bergek et al., 2008; Fagerberg, 2016), focusing on what is achieved in the system rather than on structural components of a system. In this literature, innovation performance is termed as "dynamics". Focusing on the functional aspects allows for clearly identifying policy problems and for defining policy goals. The functions are

- knowledge development and diffusion
- influence on the direction of search (basically, which mechanisms/incentives get new actors into a TIS, such as prices, regulations, technological opportunities
- entrepreneurial experimentation; "From a social perspective, the main source of uncertainty reduction is entrepreneurial experimentation, which implies a probing into new technologies and applications, where many will fail, some will succeed and a social learning process will unfold" (Bergek et al., 2008, p. 415)
- Market formation
- Legitimation ("a new technology and its proponents need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized", Bergek et al., p. 417)
- Resource mobilisation (human, financial, complementary assets)
- Development of positive externalities (mainly through new entrants and co-location of firms, akin to positive agglomeration externalities)

Fagerberg (2016) devises his own list of activities, which include knowledge, demand, finance, skills and institutions. Again, while at the policy level, there are more specific goals, there are no other innovation outcome goals other than productivity.

The multitude of policies and concepts available has also given rise to the import of the policy mix concept from economic policy. "…the term implies a focus on the interactions and interdependencies between different policies as they affect the extent to which intended policy outcomes are achieved" (Flanagan et al., 2011, p. 702). A policy mix view of innovation policy can focus attention on any trade-offs between policies, but also on policy complementarities (see Mohnen and Röller, 2005). A frequent observation for the policy mix is the importance of framework conditions not working against specific innovation policies, e.g. increasing R&D spending without making sure that enough researchers are trained may lead to inefficient R&D spending. To implement a policy mix addressing the innovation challenges of a country the OECD (2010) suggests proceeding by analysing 4 different mixes:

- Policy domain mix (e.g. not just STI policies, but also framework conditions)
- Policy rationale mix (e.g. narrow Arrow-Nelson rationales to broad NIS mixes)
- Policy strategic tasks mix (e.g. foster innovation in firms; increase contribution of public sector research, promote innovation in government…)
- Policy instruments mix (e.g. direct vs indirect, competitive vs institutional funding; supply-side and demand side)

In pragmatic approaches to innovation policy mixes, Schumpeter's triptych of invention, innovation and diffusion is often taken as a guiding lens. How well does the creation of knowledge, the introduction of innovations work (invention-based innovation)? How well does the diffusion, the adoption of technologies work? (diffusion-based innovation). These questions are usually always seen against the background of fostering innovation performance in general. In practice, innovation policies or innovation strategies set themselves a variety of performance goals, e.g. "high-tech" strategies aim at increasing the share of knowledge-intensive sectors (e.g., as in the German high-tech initiative), "catching-up" strategies aim at shortening the distance to the frontier countries (as in the case of emerging countries, see e.g. OECD 2015, p. 163), while others aim at fostering radical innovations (Friesenbichler and Leo, 2007). Also, within the overall goal of increasing the rate of innovation, there has been a shift from the main policy problem of solving the underinvestment in R&D to fostering entrepreneurship, which many policymakers and scholars now see crucial for reaping the reward from investments in R&D (Jaffe and Jones, 2013, Trajtenberg, 2009). Soete (2009, p. 401) sees as the main challenge for advanced countries the "sustainability of processes of creative destruction within environments that give premiums to insiders, to security and risk-aversiveness…" against the background of Schumpeter Mark I vs Mark II innovation regimes, i.e. of creative destruction by successful entrants which displace incumbents vs. creative accumulation by incumbents in stable environments.

Finally, Steinmueller (2009, p. 21) asks for more expertise regarding specific sectoral trajectories of innovation advance, for more evidence to conduct targeted industrial policy.

We see that there is huge complexity of policies, but that a consistent framework for intermediate goals for innovation outcomes at the sectoral level is missing. Viewing policies by their innovation outcomes at the sectoral level, by structural change towards more knowledge-intensive sectors or activities vs within-sector upgrading, could hence provide an important focusing device. That such a device is needed is observed by many authors: Steinmueller (2010) notes the problem of policy planning and implementation, where overlapping designs between countries lead to features similar to patent races, i.e. wasteful duplication. Crafting policy strategy is difficult due to the pervasiveness of issues of relevance to innovation in many different areas of government. The OECD (2015) notes that many countries share as a goal the desire to move to innovation led growth, but that innovation challenges are usually very country specific, depending on stage of development, economic structure, capabilities of firms etc. The OECD identifies the innovation challenge for advanced countries with "productivity growth"; however that is an overall economic outcome goal, and just leads in terms of innovation policy again to the same goal of increasing overall innovation performance, or the rate of innovation activity. In specific country case studies, the OECD then notes national innovation agendas and challenges, which are connected to individual innovation policies (such as the mismatch between university and industry research or support for business R&D); there is clearly a layer of goals of innovation outcomes missing to direct the policies aimed at increasing the rate (on missing directionality in innovation policy more generally, see also Edler and Nowotny, 2015).

Feller (2009, p. 109f.) notes that R&D evaluation is usually about single programmes which are too small to affect the overall economy: "Existing evaluations of R&D programs touch only lightly … on how the strategies, behavior and performance of the sectors and actors described in the national innovation system change as a result of the cumulative, long-term impact of a cluster of science and technology programs." … "Tracking longer-term structural changes in the workings of national innovation systems induced by the interaction of an aggregation of specific science and technology policies represents… a highly productive way in which economists can contribute to the design and conduct of evaluations of science and technology programs". … "The shift will be from program evaluations … for single programs, to larger, more aggregated … studies that capture both spillover effects and changing behavior on the part of key sectors and actors."

Differentiating between structural change towards more knowledge-intensive sectors and within-sector upgrading could provide one such angle whereby longer-term effect of bundles of innovation policies can be judged against. It was and is the guiding question of much research: what are policy instruments that could best serve the goals of innovation performance or outcomes? A new focusing device may make that easier for scholars and policymakers alike.

We propose our own synthesis of policies by outcome characteristic or by frontier area, following Janger et al. (2016). In their paper, the scientific frontier is the highest level of capability to expand the limits of scientific knowledge. The technological frontier is the highest level of the capability to produce innovation outputs, such as new goods with significantly changed characteristics, including intermediate outputs such as tacit or codified technological knowledge, so that the technological frontier also comprises inventive capability.[6] The technological frontier is about novelty of technological knowledge or

[6] Steinmueller, 2010 distinguishes scientific from technological knowledge by its mode of production and by its openness: scientific knowledge is knowledge produced for open disclosure with the aim of achieving recognition as

innovations. The innovation frontier is the highest level of capability to turn technological knowledge or innovations into economic benefits, e.g. value added generated by new products, or cost savings by new production processes (hence, innovation outcomes). Science policy would then aim at strengthening scientific knowledge production capabilities, as measured e.g. by quantity and quality of publications; technology policy's goal is to boost technological knowledge production capabilities, manifesting themselves in the production of tacit and/or codified technological knowledge or inventions, leading to the market introduction of innovations. Innovation policy needs science and technology policy, but aims in addition at turning knowledge produced into tangible economic benefits along two frontier areas: one is measured through growing shares of knowledge-intensive industries (structural change), the other through moving to the frontier within existing industry specializations, or climbing the quality ladder. Broader economic policies aim at productivity in general, while science, technology and innovation policies play a role in such overall economic policies.

3. Upgrading vs structural change: setting the scene

This section explains more in detail what we mean with structural change towards more knowledge-intensive sectors vs. within-sector upgrading and the underlying concepts; we relate it to the existing literature, indicating both what the approach shares with existing policy practices and analyses, but also what sets it apart as a potentially fruitful focusing device. We set out with a definition of change vs upgrading; we then relate this to the existing literature.

3.1 Structural change and upgrading as two dimensions of innovation outcomes

Past efforts to set performance goals for innovation policy which go beyond the general "increasing the rate of innovation activities" have focused on either increasing the share of knowledge-intensive sectors (witness the various "high-tech"-strategies) as an innovation outcome, or an economic effect of innovation, or on boosting "radical" innovation as an innovation output, or changing the degree of novelty of an innovation. Figure 1 presents a simple input-output framework for measuring innovation (not to be misunderstood as a linear model of the innovation process) to show how outputs and outcomes are related. The quantity of output is usually measured by counts of innovation, e.g. how many product innovations have been introduced, or by the share of firms which introduces innovations.

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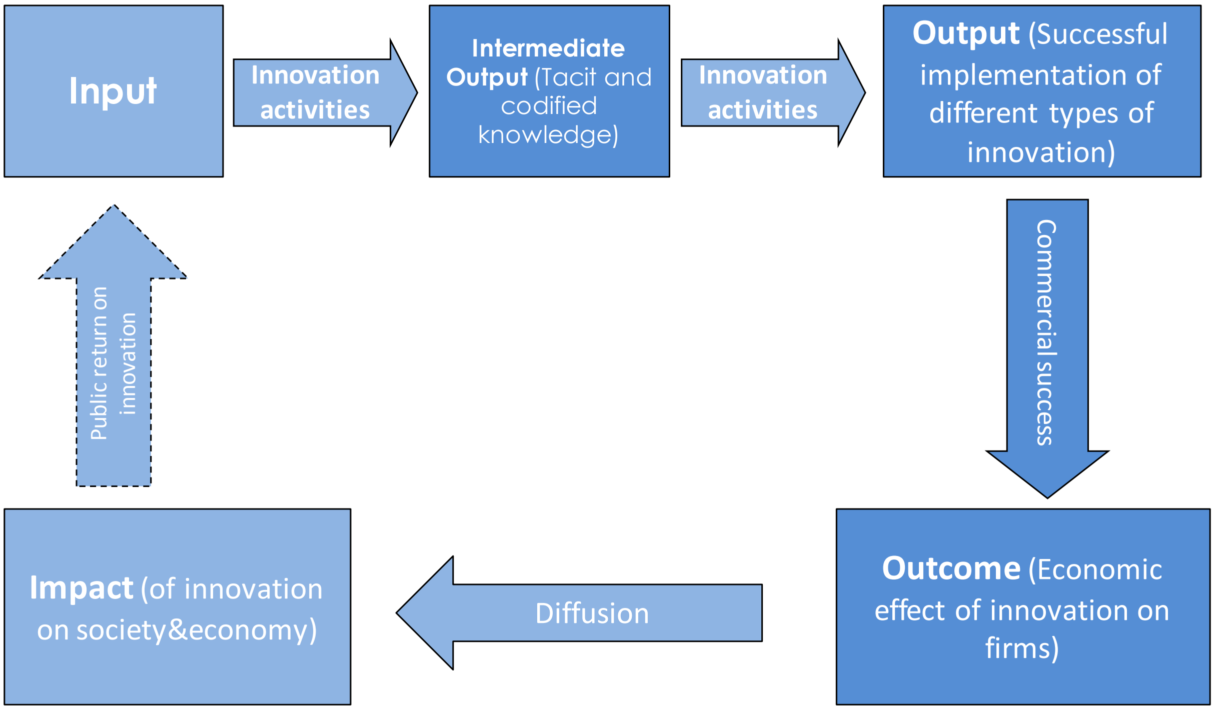
the originator (scientific priority) while technological knowledge is produced with the aim of capturing some form of exclusive rights to its use (with exclusivity protected by patents or other means, such as secrecy).

Figure 1: An input-output framework for innovation measurement



Source: Authors

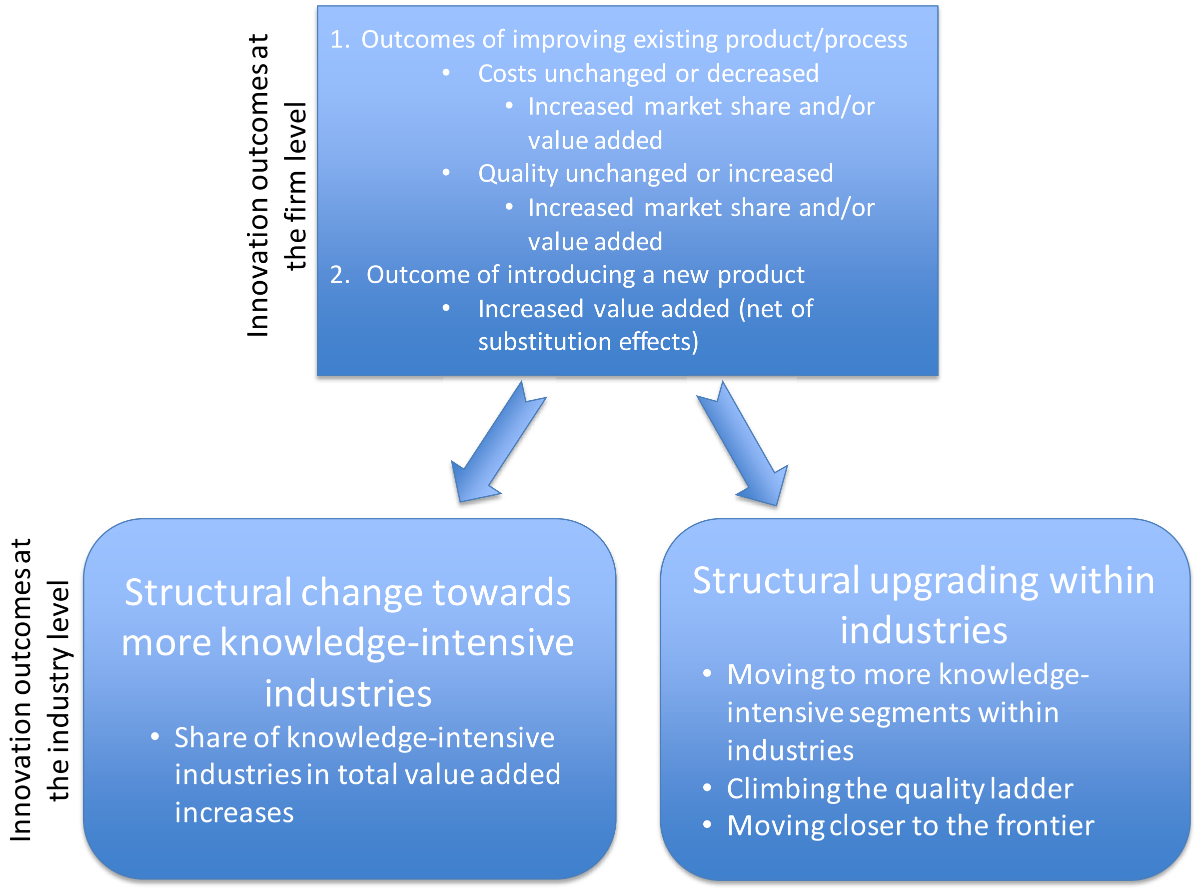
However, the quality of output, e.g., "radical" innovation or the degree of novelty, are difficult to measure and currently not suitable for guiding policy makers (see Janger et al., 2017). Moreover, for policymakers it is usually more important to make sure that innovations generate economic effects and it is not clear that radical innovation always produces superior economic effects to incremental innovation (see, e.g., Kline and Rosenberg, 1986). In other words, in terms of innovation policy-making the innovation frontier rather than the technological frontier seems to be the frontier which can be both operationalised more easily and is more attractive to policy-makers (see Janger et al., 2016). Of course, addressing technological capabilities, or the capability to create new knowledge and inventions, also influences innovation capabilities. But in terms of policy-making, focusing on innovation outcomes rather than outputs, including the success with which ideas and knowledge are turned into economic value added, may be a more effective focusing device.[7]

Recent research suggests that the economic effects of innovation, or innovation outcomes, must be reflected at the sectoral level in either structural change towards knowledge-

[7] Rosenberg and Steinmueller (1988, p. 232) in similar spirit differentiate between the scientific and the technological frontier vs the commercialisation frontier: "The Japanese have, on numerous occasions, been the leaders in the commercialization of new products, in spite of the fact that the new product, or some essential component, was invented elsewhere. Although the United States pioneered both the scientific and technological frontiers in the invention of the transistor, Japanese firms were the first to succeed in large-scale application of this technology for radios, and later obliterated America's earlier dominance of the market for color television receivers."

intensive sectors or upgrading within sectors towards more knowledge-intensive segments within these same sectors (moving closer to the frontier, climbing the quality ladder, see Janger et al., 2017). We propose to use this way of measuring innovation outcomes – or the innovation frontier - as a focusing device for innovation policy-making at the national or regional level.

Figure 2: A conceptual framework for measuring innovation outcomes



Source: Janger et al., 2017.

Focusing policies on either structural change towards more knowledge-intensive sectors or upgrading presents a middle layer of performance goals which provides new directionality in efforts to improve overall innovation performance, which was shown to be missing in our survey of innovation policy approaches. Structural change refers in our paper to growing shares of knowledge-intensive sectors in the overall economy, of either existing firms diversifying their capabilities to enter new growth areas, or new firms exploiting new market opportunities. So far, measurement and comparison of innovation outcomes at the country level has focused on shares of knowledge-intensive sectors in the economy or goods and services in exports; at the policy level, this has given rise to "high-tech"-strategies, or efforts to increase the share of such sectors, because of the presumed higher growth effects of such sectors, either directly through their growth or through higher knowledge spillovers to other sectors.

This masks a potentially much more frequent case of innovation outcomes, upgrading. In advanced countries, upgrading refers to constant efforts by firms to stay ahead of the game in their established markets, using innovation activities to deepen their capabilities ("getting better at what they do") and gain competitive advantages in cost or product quality, without changing the overall composition of economic activities. Facing growing competition from emerging countries, they need to climb the "quality ladder" of their industries to defend market shares and gain growth opportunities in hitherto untapped geographic markets. Upgrading can also be the result of new firms entering existing markets and proposing disruptive innovations, which are based on new capabilities but lead to products addressing the same needs as before (e.g. see taxis and UBER). In transition or emerging countries, upgrading can be seen as catching-up to the innovation frontier. While upgrading has always been there as a competitive strategy of firms, it was so far mostly ignored in advanced countries as an explicit performance goal for innovation policies, not least due to the absence of its measurement until recently.

It is important to note that both incremental and radical innovation can lead to upgrading and/or structural change towards more knowledge-intensive sectors. E.g., latest iterations of smartphones are technologically incremental innovations, but have contributed to an increasing share of a knowledge-intensive industry (indeed, some call the first iPhone a new combination of existing technologies, hence an incremental innovation): incremental technological innovations can lead to the growth of new product lines and markets. Vice versa, technologically radical innovations such as the jet engine merely make an existing product – in this case passenger transport – better (faster) while leaving the basic service which flows from the technology unchanged (see Janger et al., 2017). The same holds for disruptive innovations by firms such as Uber, Airbnb and Amazon, which all lead to upgrading of existing sectors rather than creating new ones. Of course, there are technologically radical innovations such as the transistor which led to new markets. But focusing on incremental vs radical innovation may not always lead to the desired economic effects. To illustrate this further, we bring a few examples.

The Finnish telecommunications firms Nokia was very successful in diversifying its capabilities when it successfully became the industry leader for mobile phones; it always used to be engaged in electronics, but big parts of its business were also related to paper and pulp. Nokia used its existing capabilities to enter a new market, a classic case for structural change towards more knowledge-intensive sectors at the sectoral level. As a result, the share of knowledge-intensive sectors in the Finnish economy rose dramatically. However, upgrading proved more difficult for Nokia, when it did not succeed in offering a commercially successful alternative to Apple's iphone or Samsung's Galaxy phones. All that time, Nokia's expenditure on R&D was higher than Apple's, and it applied for a lot of patents, so that there was creation of knowledge and technological capabilities (innovation output) – but it was not commercially successful in upgrading its line of business.

The Austrian steel manufacturer Voest Alpine has always been engaged in steel production. In spite of global overcapacity and low R&D intensity for the steel industry as a whole, Voest Alpine continually invested in R&D to develop high quality niche products, such as the longest rails for high-speed trains, getting better both technologically and commercially at what it had always been doing. Hence, through R&D, Voest Alpine managed to stay ahead in a not very R&D intensive industry, successfully upgrading its product portfolio and staying commercially viable, securing employment and growth. While the "quality ladder" in steel seems to be high enough to allow for continued differentiation among competing firms, in other sectors this may be less the case.

E.g., the Brazilian brand of flip-flops "Havaianas" (owned by footwear manufacturer Alpargatas[8]) thrives on the commercial success of marketing innovations, but the "quality ladder" in this industry seems to be inherently limited. How much further upgrading is possible against cheap competition remains to be seen. For Brazil as a whole, the question of the exhaustion of the potential for competitive advantage linked to its current specialisation profile is certainly relevant – how can change towards more presence in knowledge-intensive industries be initiated?

Finally, the internet-based computer, smartphone and app industry did not exist until recently. This marks a new industry, with firms such as Facebook, Google, Amazon, e-bay etc. all born in the last 20 years. This is a major innovation outcome and a good example for the economic benefits of structural change towards new industries.

Empirical indicators of upgrading and change show that some countries do well in the "change"-dimension of innovation outcomes, while not doing so well in the upgrading dimension (Janger et al., 2017). These are sometimes emerging countries which have managed to join the global value chains of multinational firms in knowledge-intensive industries. They are more likely to be in the less knowledge-intensive segment of such industries, featuring assembly of final products rather than innovation activities. Examples are Hungary or Slovakia, but also countries such as Ireland, with large shares of sectors classified as knowledge-intensive, but relatively little own R&D or innovation activities taking place in these sectors. Advanced countries can also have problems with upgrading, as evidenced by the problems of the US in certain sectors where they once enjoyed the lead (Autor et al., 2016; Berger and MIT Task Force on Production in the Innovation Economy, 2013; Rosenberg and Steinmueller, 1988); Nokia in Finland is a classic case, where a failure in "upgrading" has significantly reduced the share of knowledge-intensive sectors (see above).

Other countries do relatively well in the upgrading dimension, but are less good in the "change"-dimension. These are usually more advanced countries with accumulated capabilities in less knowledge-intensive sectors, where they occupy the top end of the quality

[8] http://www.imd.org/research/challenges/TC062-09.cfm

ladder. Examples are countries such as Austria, which is highly productive in industries such as metal, wood and machinery (Peneder, 1999), or Italy, which features high quality in labour-intensive industries (see Janger et al., 2011). For various reasons, they are struggling however to enter new, more knowledge-intensive industries. For these two groups of countries, a change-upgrading-focusing device could be potentially most helpful to provide directionality for innovation policies aimed at increasing the rate of innovation activities. Countries doing either well or badly in both dimensions can gain less in terms of policy prioritisation from the adoption of this approach, but the approach is still useful as an analytic guide for performance and policy analysis, as international competition is growing, global value chains spread and the search for new sources of growth amid fears of "secular stagnation" becomes more intense. The added value of the approach is in devising two broad policy bundles which have differential impact on groups of different sectors, while at the same time being neutral towards individual sectors, avoiding picking the winners or guessing market potential, a sort of "horizontal sectoral policy".

3.2 Related Literature for explaining patterns of upgrading vs. change

In this section, we relate the concept of upgrading vs. structural change towards more knowledge-intensive sectors to other strands of the literature in terms of shedding light on the drivers of innovation outcomes.

Evolutionary economics

The evolutionary literature stresses the sectoral specificity of the drivers of the process of technological change (Malerba, 2005). Technological paradigms underlying trajectories of various sectors differ by the source of knowledge they tap to uncover technological opportunities and by the conditions for exploiting such opportunities and turning them into economic benefits ("appropriability conditions", see for a survey Dosi and Nelson, 2010). Sources of knowledge in some sectors may be more frequently basic or applied research, while in others practical development and design work, learning-by-doing, may be a richer opportunity pool. The literature on STI vs. DUI modes of innovation (see Jensen et al., 2007) points out that such sources of knowledge are not exclusively used in some sectors, but that there is a difference in degree and that the successful use of different sources of knowledge also depends on firms' practices (as in its commitment to R&D and recruitment of highly skilled researchers for the STI mode of innovation, and in its adoption of organisational innovations such as quality circles, interdisciplinary or autonomous working groups to support the DUI mode of innovation).

Technological opportunities are also revealed through the needs of users or other forces of inducement such as trade union conflict (see Dosi and Nelson, 2010) so that user needs or requirements can influence the direction of search for new solutions, even though this direction of search will be constrained by the current knowledge base of a firm. Intensity of search along a given trajectory is in turn influenced by market demand. The innovative capabilities of firms are highly asymmetric, however, with in general few firms in each sector responsible for many innovations; the same asymmetric pattern applies to absorptive or adoption capabilities (see Dosi and Nelson, 2010, for a survey). Persistence in differences of abilities to innovate or imitate speaks in favour of the existence of accumulative knowledge creation, leading in turn to path dependence in innovation performance within sectors both within and across countries. The double interplay of sectoral specificities for technological advancement (trajectories) with persistence of differences in capabilities across firms would of course also contribute to explaining the observed differences in innovation outcomes as regards shares of knowledge-intensive sectors (structural change) and the movement within all sectors towards more knowledge-intensive segments (upgrading).

Persistence and path dependence imply that overall growing in sectors which are characterised by substantially different requirements for being competitive in terms of both technological and commercialisation capabilities than the sectors a country is currently specialised in asks for a different set of capabilities than improving within established sectors, or upgrading, on top of sectoral specificities in technological advancement and innovation modes. One important sectoral difference is the prevalence of Schumpeter Mark I vs Mark II innovation modes, where in the former innovation is the result of new firms entering markets and displacing incumbents (creative destruction) whereas in the latter, innovation is the result of large, stable firms in industries with high barriers to entry (see Fontana et al., 2012, for recent empirical work). Clearly, structural change towards or upgrading within Mark I industries require different sets of capabilities than structural change towards or upgrading within Mark II industries. With respect to our framework of upgrading and change, it is important to stress that the framework is neutral: upgrading can both happen by new entries (e.g. Uber in the taxi industry) or by established firms, while structural change towards more knowledge intensive sectors can be the result of existing firms (e.g. new drugs by big pharma firms) or new ones (e.g. new drugs by new pharma firms). The relevance of the Mark I – Mark II dichotomy for analysing and creating policies to influence innovation outcomes hinges on patterns of knowledge intensity.

Localised technological change, diversification and vertical vs horizontal differentiation

Reinstaller et al. (2012) show using product space indicators that diversification at the product level is mostly successful in areas close to existing specializations of a country. Comparative advantage in trade and hence the growth of an industry is more likely when diversification efforts are related to existing capabilities in an economy: "Diversification is a process in which areas of weakness develop into areas of strength by drawing on the knowledge and factor base of current areas of strength"(Reinstaller et al., 2012 p. vii). Hence, research aiming at vertical differentiation of a product in an existing market is less risky then research which tries to develop capabilities in order to enter new product markets, leading to horizontal differentiation. Akcigit et al. (2016a) find that patents close to a firm's established line of business enhance its stock market value, and that patents are more likely to be sold the more technologically distant they are to the inventing firm.[9] Unrelated diversification hence needs more fundamental research and commercialization efforts, which include significant investments in more basic research, workforce training and other complementary factors. Saviotti and Frenken (2008) argue that it is easier to increase product variety within industries than across industries. Building on established capabilities makes it easier to defend competitive advantage in existing specialisations, but can ultimately also lead to lock-ins and traps, which limit product variety and growth of new industries. This is why Unterlass et al., (2015), also find positive employment generation in EU regions from unrelated diversification. Drivers of diversification are mostly the education system, entrepreneurship, R&D and innovation subsidies as well as FDI (see Reinstaller et al., 2012, Unterlass et al., 2015).

The concept of related diversification is related to general path-dependence as explained above, and more precisely to the concept of localized technological change. Antonelli (1998) sees sunk costs as a major factor of switching costs for firms when they want to change the capital stock or the proportions in which it is used with other inputs. These sunk costs direct together with learning processes the search, development and adoption process of new technology. "*Switching in fact is not free: searching for the new techniques is expensive as is scrapping the existing tangible and intangible capital and reskilling the workforce so that it can cope with the new techniques." (Antonelli, 2008, p. 103)*

Of course, this analysis is more pertinent for capital-intensive industries where technological progress is mostly cumulative, but sunk costs can also be generated by intangible assets such as reputation or brand value. The concept of sunk costs builds on the seminal work of Sutton (1991) who modeled firms as optimally investing in building quality capabilities which leads to a reduced number of firms being able to develop such capabilities as not all firms will find it profitable to invest in R&D or other fixed outlays. This depends on the elasticity of quality responses to R&D. The higher this elasticity, the greater the incentive to invest in R&D and the smaller the number of surviving firms. The quality elasticity has been used in the empirical trade literature to characterize quality ladders in industries, or vertical differentiation. In fact, responding to the export literature emphasizing the benefits of the mix or variety of exports a country produces (Hausmann et al., 2007; Saviotti and Frenken, 2008), or horizontal differentiation, Sutton and Trefler (2016) stress that the quality of these exports also matters.

This is of course related to the notion of structural change and upgrading, but it should be pointed out that change and upgrading are concepts at the sectoral level of both manufacturing and services, whereas horizontal and vertical differentiation, and related vs unrelated diversification, are concepts at the product level in manufacturing exports. Similar in concept however, related diversification can be both based on incremental and radical

[9] Akcigit et al., 2016, p. 948, cite Gort (1962, p. 108), who stated that "when faced with a choice among activities that would be equally attractive if they were technologically equidistant from the primary one, a firm will usually undertake those for which technical propinquity to the primary activity is greatest."

innovation, e.g. merging existing technology areas can lead to the emergence of new industries (Reinstaller et al., 2012). In addition, horizontal and vertical differentiation can be seen as product-level feeders of industry-level changes in both composition of industries (structural change) and sector-specific distance to the worldwide frontier (upgrading). Janger et al. (2017) even suggest shares of countries in the top quality segments of exports as an indicator of upgrading.

National Innovation Systems

The theory of national innovation systems builds on the notion of path dependence, learning, competencies and heterogeneity of actors at the micro-level and stresses in addition the importance of how patterns of interactions and linkages among these various actors and macro-institutions affect the creation, commercialisation and diffusion of knowledge, or the performance of innovation systems at the macro-level. Systems always form to reduce complexity, in this case the complexity involved in producing commercially successful innovations. If anything, the concept of NIS reinforces the path dependence of sectoral innovation performance observed, as in addition to path dependence explained by capabilities of actors, path dependence is a result of linkages which have formed historically in a NIS and may foster certain innovation outcomes over others, as in linkages between firms, suppliers and customers, or research centres and firms, which are governed not just by contracts, but also by national specificities with respect to trust in cooperation, inter alia (see e.g. Soete et al., 2010). The result may be a reduced set of strengths in some areas, whereas in other areas competitiveness of firms is impaired by NIS deficits. Here again it is also important to stress that innovation outcomes are not just influenced by technological capabilities and knowledge, but also by capabilities to turn this knowledge into value added, and here various NIS elements clearly play a role, such as funding for innovation-intensive start-ups or human resources necessary for firm growth in production and services.

Malerba (2009) stresses that system failures may occur in the change of existing innovation systems, possibly making upgrading or the adaptation to new requirements for competitiveness in given sectors difficult, or in the emergence of new ones, preventing structural change towards specific knowledge-intensive sectors, also called a lock-in (see also Soete et al., 2010).

Varieties of capitalism

Also building on the fundamental problems of coordination firms face when engaging in innovation, the *varieties of capitalism* literature maintains that "coordinated" market economies specialise in incremental innovation while "liberal" market economies specialise in radical innovation (Hall and Soskice, 2001). In the former, firms rely more on market exchanges to coordinate their activities, while in the latter, firms build informal and collaborative relationships with the organisations involved in producing a good or a service. Characteristics of liberal (coordinated) market economies are low (high) employment protection regulation, high (low) stock market capitalisation, a focus on general (vocational) skills provision by the education and training system and the absence (presence) of industry-wide employer associations. These characteristics are not independent of each other, but form institutional complementarities.

This approach is different to differentiating between structural change towards more knowledge-intensive sectors and upgrading, as the economic benefits of incremental vs radical innovation do not automatically translate into structural change vs upgrading (see also Janger et al., 2017). Both, radical and incremental innovation, can contribute to either (see the examples above), and Akkermans et al. (2009) show that CMEs specialise in radical innovation (or rather inventions, as they use patent data) in machinery and transport equipment manufacturing, while LMEs specialise in radical innovation in chemicals and electronics. Hall and Soskice (2001) opted for what they call "radical innovation" as an empirical test for their hypothesis; however, in explaining how institutional complementarities work together in creating competitive advantages, they talk more about economic specialisation, rather than about certain kinds of codified knowledge (i.e, patents). In LMEs, companies competing in rapidly changing markets have it easier due to more mobile tertiary educated labour and capital market funding of risky projects, while in CMEs, companies competing in markets building on cumulative capabilities and relational contracting enjoy institutional advantages, e.g. by being more able to provide long-term labour contracts to people equipped with firm- or industry-specific skills. While many things have changed since 2001, an institutional approach to explaining differences in competitive advantage in rapidly changing or emerging industries vs. cumulative industries certainly continues to be relevant for innovation policy-making.

In similar spirit, already Abramovitz (1986, p. 388) referred to social capability as a determinant of catching-up and noted "… the familiar notion of a trade-off between specialization and adaptability. The content of education in a country and the character of its industrial, commercial, and financial organizations may be well designed to exploit fully the power of an existing technology; they may be less well fitted to adapt to the requirements of change." In his view, adaptability implies an interaction between social capability and technological opportunity: "The state of education embodied in a nation's population and its existing institutional arrangements constrains it in its choice of technology. But technological opportunity presses for change. So countries learn to modify their institutional arrangements and then to improve them as they gain experience." (Abramovitz, 1986, p. 388) He hypothesised social capability to also depend on openness to competition, to the establishment of new firms and to the sale and purchase of new goods and services.

In a similar vein, more at the level of organisations and the innovation process and less at the institutional, country-level side, Rosenberg and Steinmueller (1988) point out two distinct sets of capabilities when analysing why the US is a supposedly "poor" imitator by comparison with Japan, one relating to the early stages of the innovation process, in terms of new knowledge generation, the other related to efficiently using this new knowledge in the production process, i.e. turning that knowledge into economic benefits for the firm which generated the knowledge. Development activities (the "D" in R&D) are seen as facilitating commercialisation and economic advantages over competitors focusing on research only. It is worth stressing that while both argue in terms of radical vs incremental innovation, Rosenberg and Steinmueller talk about the advantages of Japan (a coordinated market economy), while Hall and Soskice provide a neutral, sector-specific picture; and many others criticise the performance of Germany, Japan or Europe in general in terms of generating fast-growing, innovation intensive firms.

Box 1: Rosenberg and Steinmueller (1988) on innovation vs imitation in the US vs. Japan

"The first part of our answer to the question of why Americans have been such poor imitators is that there has been a distinct asymmetry in the strengths developed by each of these industrial economies. … The Japanese have been very successful in borrowing and developing technologies initially created by American firms…, in particular, a stream of highly visible product innovations.

By contrast, what may be most worth imitating on the Japanese side is much more subtle and much less visible. It includes ways in which certain activities are carried out, rather than readily identifiable pieces of hardware. These differences lie at the levels of organization and incentives for improvement. The first is the efficient coordination of product design and manufacturing functions. The second is effective solutions to the myriad small problems that are key to efficient mass production techniques.

… American thinking about the innovation process has focused excessively upon the earliest stages - the kinds of new products or technologies that occasionally emerge out of basic research, the creative leaps that sometimes establish entirely new product lines, the activities of the "upstream" inventor or scientist rather than the "downstream" engineer. American discussions of technical change are more likely to be presented in terms of major innovations and pioneering firms, rather than in terms of the success of particular sectors or firms at catching up and overtaking other organizations through sustained effort and small improvements. In this respect, the dominant view of the innovative process is still overly Schumpeterian, in its preoccupation with discontinuities and creative destruction, and its neglect of the cumulative power of numerous small, incremental changes. We suggest that the Japanese have had a much deeper appreciation of the economic significance of these vital development activities than their American counterparts. … in the internal organization of their firms, the Japanese commonly provide for much closer interaction between product designers and production engineers, they devote far more attention to the refinement of the appropriate process technologies, and they also assign a more prominent role to the engineering department.

[1] In considerable measure, then, their skill in imitation has been an accompaniment of their skill in, and concern with, development activities. The significance of these activities is heightened by a recognition that the ability to imitate and improve upon one's own prior performance, rather than starting from scratch, is often central to success at development activities. If American industry were to improve its development skills it would also, simultaneously, improve its capacity to imitate. The two capabilities overlap heavily…. These

activities are not well appreciated when, as is commonly the case, development is thought of as the application of scientific knowledge.

[2] Development in fact incorporates knowledge from many sources. … Organizational structures and incentive systems that can exploit these sources effectively will create economic advantages over competitors who cannot do so, even if these competitors have superior research capability. If these development capabilities are sufficiently strong, the stage of commercialization may be reached sooner, and will certainly be reached by firms in a better position to subsequently reduce cost and improve performance (Masahiko Aoki and Rosenberg, 1987).

In short, the economic value of "first-mover" advantages in capturing the economic returns from innovation is overrated, because innovations are commonly very poorly designed in their earliest stages and in numerous ways ill-adapted to their ultimate applications […] The incremental improvements underlying development play a critical role in the eventual capture of returns from innovation." (Rosenberg and Steinmueller, 1988, p. 231)

3.3 Intentional policies

Such historically developed innovation systems or institutional complementarities can of course be influenced by intentional policies. Ergas (1987) notes systematic differences in technology policies between the United States, the United Kingdom, and France, which he characterises as "mission-oriented", and diffusion-oriented countries such as Germany, Switzerland, and Sweden. The former focus technology policy on "big problems" such as defence, health and education with a view to achieve strategic technological leadership, while the latter aim at encouraging the best use of a technology within existing patterns of specialization with a view to help domestic firms to be internationally competitive.

More recently, Freeman and Soete (2007, p. 280) juxtapose the success of the US in providing incentives for Schumpeter Mark I innovation processes (i.e. of creative destruction driven by new entrants) through the Small Business Innovation Research (SBIR) programme, the lower cost of patenting and SME-friendly public procurement with the dominance of Schumpeter Mark II in Europe, characterized by large incumbent firms in search for innovation rents and defence of international competitiveness. Precisely the Schumpeter Mark 1 dynamism may be needed in their view for advanced countries to grow along the technological frontier. A very different view is taken by Berger and MIT Task Force on Production in the Innovation Economy (2013) who want to analyse the reasons behind a dwindling manufacturing sector and trade deficits even in advanced technology products in the US, again pointing to the issue hinted at by Rosenberg and Steinmueller (1988) of the difficulties in the US to capture the flow of economic benefits from invention and entrepreneurship. While start-ups in emerging technology sectors may be created in the US, often the jobs associated with larger scale production move abroad. And most importantly, the industrial ecosystem necessary for the creation of new firms and for upgrading, has become full of "holes". Some capabilities related to learning in the early commercialization stages are simply not there anymore, and given the importance of geographic proximity for innovation processes, this lack of capability may negatively affect future growth in the US ("the ties that connect research in its earliest stages to production in its final phases remain valid", p. 11). Berger and MIT (2013) use the notion of an industrial eco-system which is linked to the relational view of the firm also shared by the varieties of capitalism-approach. Unlike Germany, in the US many information sources for developing and commercializing products such as trade associations, community colleges, research consortia, institutes such as Fraunhofer, outside funding for medium-sized manufacturers seem to be deficient.

"Innovation in Germany builds on legacies: on industrial specializations, longstanding relationships with customers, workforce skills, and proximity to suppliers with diverse capabilities. The potential of German patterns extends well beyond defending niches against low cost competition with incremental advances. They create new businesses, not usually through start-ups—the U.S. model—but through the transformation of old capabilities and their reapplication, repurposing, and commercialization. The companies we interviewed had moved from autos to solar modules, from semi-conductors to solar cells, from machine tools to make spark plugs to machines to make medical devices like artificial knees. It's impossible to understand the different fates of manufacturing in the U.S. and Germany without comparing the density and richness of the resources available in the industrial ecosystem across much of Germany to the thin and shrinking resources available to U.S. manufacturers across much of our country." (Berger and MIT, p. 26/27) This is a classic description of using existing technological capabilities to horizontally diversify into new product markets, or structural change.

Berger and MIT see the decline of vertically-integrated enterprises in the US behind this, as these firms used to have the resources to educate and upgrade the skills of the workforce and to scale-up production of new products, something small spin-offs out of university labs usually don't have. The demise of vertical integration is associated with the model of corporate ownership in the US more than with globalization or the rise of China, as in their view firms focused on core competencies in order to maximize short-term profit. Berger and MIT identify four key functions that such firms once fulfilled: convening, coordination, risk-pooling and risk- reduction, and bridging. "Convening" leads to new collaborations and new common resources, while risk-reduction and risk-pooling are classic insurance and standard setting functions, usually provided by all trade associations for their members. Helper and Kuan (2016) note that US suppliers value Japanese customers for their willingness to invest in 'relational contracts' with suppliers, providing training and management assistance to them, in return for 'continuous improvement' in costs. In the survey by Helper and Kuan (2016) US automakers were perceived by suppliers as making unreasonable demands for frequent price reductions and offering little technical or organisational support for capital-intensive innovation efforts. After this review of related literature, the next section focuses on singling out potential drivers of structural change and upgrading.

3.4 Potential factors driving structural upgrading vs. change

Which factors will foster structural change towards knowledge intensive sectors, which upgrading in existing sectoral specialisations? Why does the performance in structural change and upgrading vary across countries? We recall that the concepts of structural change and upgrading are not about incremental and radical innovation. Firms such as Uber and Amazon have disrupted traditional low-tech sectors with radical innovations, leading to an upgrading of these sectors. While the Apple Iphone is seen as a technologically incremental innovation which combined several new technologies into a new product, it led to the emergence of a new product category, the smartphone, which is now a multibillion dollar industry. We see incremental and radical innovation as concepts relating to functional performance improvements of existing or new products and processes (such as less fuel consumption, new services which did not exist before) which relate to the technological frontier.

Structural change and upgrading define the innovation frontier, or the capability to transform innovations into commercial success, as expressed by the value added they generate. The economic benefits of an innovation depend not so much on its technological radicality than on its "service" characteristics (see Saviotti and Metcalfe, 1984), i.e. whether new product categories are entered and new markets are created. E.g., both the US electric car pioneer Tesla and the Austrian start-up battery firm Kreisel have developed batteries for cars, but use a similar technology for home energy storage solutions, which is a very different market.

Of course, partly the same factors drive the technological and the innovation frontier (and both are influenced by factors driving the scientific frontier); and within the innovation frontier, also structural change and upgrading will be partly driven by similar factors such as the quality of regulation and government in different areas, including basic issues such as tax collection; many factors work at an aggregate level positively for both change and upgrading. Openness to trade and FDI is in principle good for competition and may provide incentives for upgrading against international competition, but it also enables the absorption of new knowledge and linking into global value chains which stimulates structural change. Spending on R&D can reinforce specialisation patterns as existing capabilities are deepened or lead to diversification as capabilities are broadened. The overall quality of an education system will also be a base for both upgrading and change, as they both require skilled employees. Differences may only emerge when looking at differences within policies and framework conditions. We will try looking at factors which overall may have a tendency to be rather fostering one kind of innovation outcome over the other.

At the sectoral level, we will try to hypothesise about factors which foster the emergence or the growth of new knowledge-intensive industries vs. which ones help firms moving up the quality ladder, defending competitive advantage in established industries. Of course, as soon as new knowledge-intensive industries are established, their growth will hinge on successful upgrading. Factors which drive change vs upgrading must also be seen against the context of sectoral specificities, or sector-specific requirements for firm competitiveness, which may change over the life-cycle of an industry. However, as examples such as Amazon for retail, Uber for taxis and Tesla for cars demonstrate (essentially upgrading through firm entry), the concept of life-cycle should not be applied statically to the evolution of all industries.

But an analysis of which factors affect a tendency of new industry emergence vs. upgrading of existing ones will also have to go down to the firm level, e.g. for R&D subsidy programmes. At the firm level, we define structural change towards more knowledge-intensive sectors/activities as an event where firms use an expansion of their capabilities to enter or create new product markets, while upgrading relates to defending/increasing market shares in existing business lines, both through technologically advancing the frontier or catching up to it. We hypothesise based on the existing literature that the following factors will tend to be more beneficial for either change vs. upgrading:

Factors potentially supporting upgrading more than structural change

Framework conditions

- Framework conditions which help relational contracting, exchange of information between suppliers and customers, such as the presence of trade or employer associations; this is usually also related to historically grown business models in dealing with suppliers and customers

Education system

- Opportunities for workers to become highly skilled in long-term training on the job, such as in apprenticeships, able to spot problems in production and to contribute to incremental innovations related to production processes, as well as to adopt and learn the use of external technologies for own needs;
- In tertiary education, local or regional tertiary institutions with curricula catered to business needs or to regional skill needs

R&D and innovation policy

- Many countries run innovation or R&D grant support schemes. To support upgrading in established specialisations, several options are potentially available:
    - A thematic funding focus on existing industry strengths (with the usual pitfalls of top down rather than bottom-up funding)
    - Bottom up funding which selects R&D projects on quality only may yield the same results, in that most of the funding will go to the areas of the economy which have established comparative advantages.

   - Project selection criteria can be tilted towards projects that are technologically risky and ambitious, but that serve towards improving established market positions of firms
- There is some evidence (eg. OECD 2016, Widmann 2016) that R&D tax credits foster incumbents and established lines of research. This depends however on the design of the instrument in question.
- For firms close to the frontier, research cooperation with research institutes and universities may trigger technologically more radical improvements which help them to expand or defend existing lines of business[10]. Business-science research cooperation will have a tendency to deepen knowledge needed for existing specialisations, as the ideas and the research needs will be influenced by applied business needs.
- For SMEs with lower research capacity, or firms further away from the frontier, cooperation with more applied research institutes or sectorally or technologically specialised intermediaries (such as Fraunhofer in Germany; Danish industry research institutes eg. pig farming institute SEGES) which provide information to firms on how to improve products/processes will be beneficial
- Overall, a rich and dense industrial eco-system around firms, with product development relations with suppliers and customers as well as R&D cooperation with research institutions and skill needs supplied by regional educational institutions will help firms to stay competitive in their established line of business
- As outlined above, entrepreneurship can be a very powerful factor for structural upgrading of a sector. This is related to sectoral technological regimes (see the discussion on Schumpeter Mark I and Mark II industries). If upgrading occurs mainly through new establishments displacing incumbents, this requires re-allocation of production factors, so that mobility of production factors would be a factor supporting upgrading. One needs to differentiate between start-ups in emerging product lines or industries and start-ups disrupting existing lines of businesses. On balance, entrepreneurship may however be more related to structural change; this could also differ by country, with countries such as the US better at upgrading through new market entrants, while firms in Continental Europe are more apt at reforming themselves to stay competitive.

[10] E.g., in a cooperation between the Technical University of Graz and Siemens, engineers managed to cut the weight of the chassis of rolling railway stock by 50%. This amount of weight reduction in a relatively mature line of products is technologically certainly not incremental.

Factors potentially supporting structural change more than upgrading

Factors for structural change may differ between countries close to the frontiers in STI and countries further away from the frontiers in STI. In the latter, a growing share of knowledge-intensive sectors may be the result of linking into global value chains through competitive cost structures, reliability, good logistics and infrastructure; for higher income countries, change through diversifying research and innovation capabilities – we focus on high income countries.

Framework conditions

- Framework conditions enabling quick moving of factors of production, such as mobility of highly skilled labour and capital (labour and capital market regulation); for start-ups, this will be more likely to be venture capital funding rather than e.g. internal funding based on cash flow. Product market regulation may also play a role.

Education system

- Tertiary graduates from higher education institutions which focus on basic research may be more likely to contribute to a broadening of capabilities fuelling change towards knowledge-intensive industries
- Spin-offs from academic/basic research institutions may be more likely to lead to the growth of knowledge-industries
- The quality of academic research is likely to matter, as empirical evidence shows that it both facilitates the creation of spin-offs and the attraction of talented researchers and students. The distance to the scientific frontier seems to play a role in both the attraction of talents and in creating USPs or unique selling propositions for start-ups based on novel knowledge. Talented graduates can fuel the growth of innovation-intensive spin-offs/start-ups or engage in developing new product lines in established firms.
- Top universities are especially a source for firm research at the industry level (Adams and Clemmons, 2008)

R&D and innovation policy

- Entrepreneurship, growth of new firms (see above); young and small firms need strategies for commercialisation, for scaling-up of production, in order to become relevant for the growth of knowledge-intensive industries.
- The governance of emerging industries probably needs more attention from policymakers than established industries do, in terms of setting and diffusion of standards, regulations, etc.
- Innovation funding agencies
    - A thematic funding focus on growth in new industries (with the usual pitfalls of top down rather than bottom-up funding), whereby as discussed above new areas of strength are more likely to emerge when they share capability requirements with established industries; e.g., a country specialised in machinery, metals, may be more effective in fostering environmental technologies related to this core set of capabilities rather than areas with little relationship to them, such as pharmaceuticals; some funding for "crazy" projects could keep options open however.
    - Project selection criteria can be tilted towards projects which develop or adapt competencies so that new markets can be served (new products), i.e. which show a focus on commercial diversification. In this case, demonstrating big jumps in the technological status quo may not necessarily be needed – when it is enough to incrementally change existing capabilities for entering a new product market, but when the new market entails substantial "innovation" risk in terms of successfully managing the commercialization of the new product. High technological and innovation risk could be rewarded with higher matching rates (i.e. a higher share of costs subsidized), as search and switching costs are usually higher for firms in this case (see discussion above).
    - This may also involve fostering basic research of firms. Akcigit et al. (2016b) show for a sample of French firms that the investment into basic research increases as the scope of a firm's activities expands, even after controlling for firm size. This may be due to the fact that "as the range of a firm's products and industries becomes more diversified, its incentive for investing in basic research relative to applied research should increase due to better appropriability of potential knowledge spillovers" (p. 3).
- Public procurement of innovation has a role to play in reducing commercial uncertainty for new products, so that growth of new industries could be demand-led.
- Policies may also influence the direction of search (basically, which mechanisms/incentives get new actors into new markets, such as prices, regulations, technological opportunities…)

We view these potential factors driving upgrading vs change as a challenge for empirical research. A comprehensive analysis taking account of endogeneity will require data which are currently only partly available. One example is data on how innovation funding agencies select projects and how this affects change vs. upgrading. Not even to mention different project selection criteria in terms of fostering upgrading vs change, Bronzini and Piselli (2016) and Widmann (2016) note that most studies on the effect of firm R&D subsidies look at the effect on firm's own R&D expenditures, rather than on more output our outcome related effects such as patents, value added, product diversification etc.

Next to the issue of data availability, we may face issues of policy complementarities (Aghion et al., 2009; Mohnen and Röller, 2005), e.g. when specific R&D and innovation are ineffective without appropriate education policies and framework conditions. While there are bound to be "policy bundles" or appropriate policy mixes fostering change vs upgrading, including a variety of policies and framework conditions (such as, e.g., a combination of top research universities with venture capital availability), there not need be trade-offs as in the varieties of capitalism literature, where pursuing policies to foster structural change would harm upgrading. Indicators on change vs upgrading (Janger et al., 2017) show that some countries do well in both areas, such as the Nordic countries, which combine flexible labour and product markets with ambitious education, R&D and innovation policies. This is also linked to the fact that we don't see incremental and radical innovation as the defining issue; as we have made clear, both types of innovations can lead to either change or upgrading effects.

Another factor complicating empirical analysis is that current country performance with respect to structural change and upgrading is not just the result of recent policies and current framework conditions, but is bound to be the result of a "dynamic co-evolution of knowledge, innovations, organisations and institutions" (Soete et al., 2010, p. 23) over time, so that different constellations of policies, institutions and firm capabilities may lead to different effects of the same kind of initiative or policy in different countries. "Policy intervention could indeed be desirable or even necessary but had now to be informed by local conditions and based on the study of innovation processes, organisations and institutions and their interactions over relatively extended periods." (Soete et al., p. 23).

The feasibility of an innovation policy strategy targeting change vs upgrading hinges obviously on empirical results showing that there are cross-sector drivers of change vs upgrading, controlling for other cross-sector characteristics such as cumulativeness and basicness of knowledge. Here we may also point out the difficulty that once a new industry has become established, upgrading also becomes a challenge as upgrading encompasses all sectors. An empirical analysis of shares of knowledge-intensive industries in a country may hence just reflect successful upgrading in sectors established a considerable time ago, but which are still knowledge-intensive. Sectoral empirical strategies may hence be difficult, so that firm level analysis focusing on new product lines vs established product lines could be more fruitful, or qualitative case studies on new industry emergency and successful industry upgrading or transformation. In that regard, for structural change, probably more can be learned from the problems of Continental European countries in replicating the US Silicon Valley, while for upgrading, more can be learned from the problems of the US in upgrading traditional manufacturing industries.

Empirical evidence on the related phenomenon of export diversification vs specialisation is provided by Reinstaller et al. (2016) – also part of the current study - who find that increasing human resources in science and technology (HRSTC) and tertiary educated people in the workforce favours diversification into products that are more distant from the current specialisation profile, even though their importance varies with the level of technological and economic development: in the more advanced economies, changes in both the share of tertiary educated people and HRSTC in the workforce work as a substitute for local capabilities and therefore allow diversification into products that are more distant from the current specialisation profile. In all likelihood, progress on backing up this strategic policy framework with empirical results will proceed partially, by investigating specific factors, rather than being able to carry out a comprehensive analysis.

4. Conclusions

This paper has tried to look at within-sector structural upgrading vs structural change towards more knowledge-intensive sectors as a focusing device for innovation policy, responding to country-specific challenges. This concept is meant to reflect the innovation frontier, as opposed to the scientific and the technological frontier. It is potentially very relevant for policy as scientific and technological knowledge need to be commercialized in order to become relevant for economic and societal goals. A review of the innovation policy literature shows that this framework could provide a missing directionality in approaches to improve innovation performance. The paper shows that there are related strands of analysis out there which come with their own policy results, but also shows the differences between these concepts and a focusing device of upgrading vs change. Based on the existing literature, a list of factors is drawn which need to be empirically verified. In this regard, the paper aims at laying the conceptual groundwork for further more empirically oriented research. A first step is made by a twin paper to this study by Reinstaller et al., (2016), who find that increasing human resources in science and technology (HRSTC) and tertiary educated people in the workforce favours diversification into products that are more distant from the current specialisation profile.

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