ETLA

Raportti | Report | 99

12.3.2020

Innovation Promotion Rationales and Impacts – A Review

Eero Aalto
Aalto University, Finland
eero.aalto@aalto.fi

Robin Gustafsson
Aalto University, Finland
robin.gustafsson@aalto.fi

Suggested citation:
Aalto, Eero & Gustafsson, Robin (12.3.2020). "Innovation Promotion Rationales and Impacts – A Review".

ETLA Report No 99. https://pub.etla.fi/ETLA-Raportit-Reports-99.pdf

Abstract

We review the extant research on the government innovation promotion rationales and impacts. Based on the research literature, the review synthesizes innovation promotion rationales, economic justifications for the intervention, impact evaluations of innovation promotion interventions, and current forms and mechanisms of innovation promotion.

We identify four main rationales and economic justifications for government intervention in promoting research, technology development, and innovation: (1) the market failure rationale; (2) the system failure rationale; (3) policy outcome rationale from positive spill-over effects from research, technology development and innovation; and (4) four mission oriented policy rationale, including grand societal challenges, responsible innovation, demand-side innovation policy, and public sector innovation.

Recent impact evaluation evidence show, in general, more positive than negative outcomes from innovation promotion. Research designs still include high degree of heterogeneity, and thus has some mixed results. Studies are still divided on the crowding-out effect, and to which extent interventions translate into long-lasting benefits. We find tentative positive impacts on broader policy goals seeking for societal and economic benefits. Future public policies and impact evaluations should seek to incorporate more holistic and longitudinal designs.

Tiivistelmä

Katsaus innovaatiopolitiikan merkityksestä

Raportti kerää kattavasti yhteen innovaatiopolitiikan oikeutusta ja vaikuttavuutta käsittävää tutkimuskirjallisuutta.

Erityisesti keskitytään innovaatiopolitiikan perusteluihin, julkisen intervention taloudellisiin syihin, innovaatiopolitiikan vaikuttavuuteen sekä nykyisen julkisen intervention muotoihin ja mekanismeihin.

Julkisen sektorin antamalle tutkimus- ja kehitystyön sekä innovaatiotoiminnan tukemiselle löytyy neljä hyvää perustelua: (1) markkinavirhe, 2) järjestelmävirhe, (3) lopputulema, joka tarkoittaa innovaatioiden taloudellisia ja yhteiskunnallisia heijastusvaikutuksia yrityksille, toimialoille ja koko taloudelle, sekä (4) tavoitesuuntaus, joka käsittää yhteiskunnallisten haasteiden ratkaisut, vastuullisen innovaatiotoiminnan, kysyntäpuolen innovaatiopolitiikan ja julkisen sektorin innovaatiot.

Tutkimuksen mukaan julkisen intervention vaikutus on keskimäärin positiivinen sekä yritysten kilpailukyvylle että kansantaloudelle.

Tutkimusasetelman erojen vuoksi tulokset ovat osittain ristiriitaisia. Tulokset eivät siksi vastaa yksiselitteisesti siihen, missä määrin julkinen interventio syrjäyttää yksityistä toimintaa ja millä tavalla innovaatiopolitiikan vaikutus näkyy pitkällä aikavälillä. Alustavien tulosten mukaan innovaatiopolitiikan vaikutus on positiivinen laajempien tavoitteiden toteuttamisessa. Innovaatiopolitiikan suunnitteluun ja vaikutusarviotyöhön tarvitaan kokonaisvaltainen painotus ja pidemmän aikavälin huomiointi.

M.Sc. (Political science) **Eero Aalto** is a Doctoral Candidate at Aalto University.

D.Sc. (Technology) **Robin Gustafsson** is an Associate Professor of strategic management at Aalto University.

VTM **Eero Aalto** on Aalto-yliopiston tohtorikoulutettava.

TkT **Robin Gustafsson** on strategisen johtamisen professori Aalto-yliopistossa.

Acknowledgements: This review was funded by Business Finland. A special thanks to the invaluable inputs from the steering group of this research project, Teppo Tuomikoski, Heli Karjalainen, Hannu Kemppainen, Christopher Palmberg, and Jari Hyvärinen. A special thanks to ETLA for the community, the support, and hosting of Robin Gustafsson when finalizing the manuscript.

Kiitokset: Business Finland rahoitti tämän katsauksen. Erityiskiitokset hankkeen ohjausryhmäläisille, Teppo Tuomikoskelle, Heli Karjalaiselle, Hannu Kemppaiselle, Christopher Palmbergille ja Jari Hyväriselle. Erityiskiitokset myös Etlalle Robin Gustafssonin tutkijavierailun mahdollistamisesta ja avusta julkaisun viimistelyvaiheessa.

Keywords: Innovation policy, Impact evaluation, Policy rationales, Innovation promotion

Avainsanat: Innovaatiopolitiikka, Vaikuttavuusarviointi, Politiikka-rationaliteetit, Innovaatiotuki

JEL: L53, O38, O30

Contents

This review is organized into two parts. This first part synthesizes innovation promotion rationales. The second part synthesizes what is known today of the impact of innovation promotion, through a careful review of over 70 articles.

Part I. Innovation promotion rationales

The first part broadens and extends the analysis of innovation promotion rationales as well as makes an updated review, of the syntheses on the market and systems failure rationales by Gustafsson & Autio (2011), through analyzing over 50 additional articles.

Research, technology, and innovation policy

Research, technology development, and innovation promotion policies have been the focus of nations and economic regions for the last thirty years (Edler & Fagerberg, 2017). Innovation refer to "the introduction of new solutions in response to problems, challenges, or opportunities that arise in the social and/or economic environment" (Edler & Fagerberg, 2017:4). Innovation policy is the "public intervention to support the generation and diffusion of innovation" (Edler et al., 2016:3). Innovation promotion means to "fostering the use of the best science and technology to produce new and competitive 'first-to-market' products and new production processes, and the innovative organizational approaches and management practices to support these activities" (Doern & Stoney, 2009:9). Until the end of 1990s (early 2000), technology policy was used instead of innovation policy, to address the stimulation of research and technology development (Metcalf, 1995), but also more broadly as a policy to foster the value of "technological knowledge and activities embedded within firms, and necessary not just for new ideas and innovations, but also to enable effective assimilation of knowledge – technological and scientific" supporting firms ability to not only get ahead in technological progress but also for developing the capacity to keep up (Pavitt, 1987). Research policy refers to "policies aimed at the funding, conduct and dissemination of basic and applied research in the natural, health and social sciences" (Martin, 2016:8).

Policy rationales and economic justifications for intervention

Based on our study of past research on rationales and economic justifications for government intervention in promoting research, technology development, and innovation, and facilitating spill-overs, we identify four distinct main rationale types (1) the ***market failure rationale;*** (2) the ***system failure rationale***; (3) ***policy outcome rationale*** arising from economic and societal benefits from positive spill-over effects from research, technology development and innovation to firm, industry, region, and economy (additionalities); and (4) ***mission oriented policy rationale***. We next discuss each of these in more detail.

The market failure rationale

The central premises for public intervention in R&D and innovation has been the market failure rationale. The three underlying mechanisms for the market to underinvest in research, technology development and innovation are (1) the non-proprietary nature of knowledge, especially technological knowledge; (2) the inherent economic risks and uncertainties in research, technology development, and innovation; (3) externality benefits of technologies not accounted for by the market.

Non-proprietary nature of knowledge

As knowledge is visible in work practice, new goods, and services, it will inevitably leak, and the original investor will not be able to fully appropriate all the returns of her investment (Arrow, 1962a,b). Knowledge as such can be considered a public good. The developer(s) of new technologies, new technological knowledge and innovation cannot exclude others from using what is visible and known and others from capturing rents from investments made in research, technology development and innovation. This is also called the free-rider problem. Furthermore, technological knowledge is a non-rivalrous good as ones consumption of that good does not prevent anyone else from using or benefiting from that good. Further, the use of technological knowledge by others does not

require them to invest the same amount that the one that originally develop the new technological knowledge. Underinvestment in knowledge production therefore follows, as actors see the opportunity to utilize new knowledge without investing in exploration (Gustafsson & Autio, 2011).

Economic risks and uncertainties in research, technology development, and innovation

Research, technology development, and innovation are highly uncertain activities, they have long lead times, and are collective and cumulative processes (Lazonick & Mazzucato, 2013). Engagement in research, technology development and innovation is as such a collective multi-party investments and learning process "that involves, first and foremost, a strategic confrontation with technological, market, and competitive uncertainty" (Lazonick & Mazzucato, 2013:1093). Due to the inherent uncertainties of innovation processes, one cannot calculate a probabilistic stream of financial returns at the time when investments of effort and money in the innovation process are made (Mazzucato & Tancioni, 2012). In addition, the cumulative character of innovation process requires "committed finance – or what is often called "patient capital" – to sustain the innovation process from the time at which investments in innovation are made until the time at which those investments can generate returns" (Lazonick & Mazzucato, 2017:1101)". This means that the cumulative character of innovation "makes the innovation process highly dependent on access to financial resources that will sustain the innovation process from the time at which investments are made until it can generate financial returns (Lazonick, 2010). Important here to note is also that impactful innovations, i.e. the mobile phone technologies, healthy food ingredients (probiotics), and biofuels production, go through drastic changes in their lifetimes – changes that may, and often do, totally transform their economic significance. The "subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form." (Kline & Rosenberg, 1986, 283). Furthermore, the risks and uncertainties growth the further away one goes from commercialization to research. Research and applied research require hence more trial and error than innovation (Janeway, 2012). Such activities in research has also been termed frontier research, referring "to the risk-taking behavior of rugged competitive individualists pioneering into the unknown" (Flink & Kaldewey, 2018:16).

Externalities of technologies not accounted for by the market

There are multiple kinds of externalities in regards to technology not accounted for by the market. This means that the price mechanisms does not reflect externality benefits of technologies, nor possible negative externalities. We distinguish between five kinds of externalities not accounted for by the market: (1) *technological and infrastructural public good externalities*; (2) *merit goods and service externalities*; (3) *pecuniary good externalities*; and (4) *negative externalities from technologies*.

Technological and infrastructural public good externalities

For non-exclusive and non-rivalrious public good externalities, the demand and price mechanisms may fail to produce sufficient incentives for their production on a commercial basis (Romer, 1990; Samuelson, 1954). The market may break down due to high transaction costs, high up-front investment, and non-excludability. Under such conditions, the production of technological and infrastructural goods may be taken up by the public sector. (Gustafsson & Autio, 2011:822)

Such technological and infrastructural technologies, i.e. railways, electricity grid, city infrastructure, require high fixed cost investments in physical infrastructures and knowledge bases. They have the character of public goods as it is hard to exclude usage and appropriate directly fees from users. Thus, it has been in past the government (representing the collectivity of taxpayers) that have had to initially engage in this strategic confrontation with uncertainty (Mazzucato, 2011; 2013).

Merit goods and service externalities

Merit goods provide savings by preventing future cost escalation. Such goods include, for example, preventive health care as well as technologies that reduce traffic accidents. Merit goods thus benefit society by proactively reducing the need for, e.g. future welfare services. While the societal benefits are clearly positive, the market price mechanism may fail to correctly reflect their value for the society, and thus prevent their production on a commercial basis. (Gustafsson & Autio, 2011:822)

Pecuniary good externalities
Pecuniary goods are products and services that deliver efficiency gains which are not reflected in the price. In the 1950s, several microeconomic studies started to explore consumer surplus (also referred to as pecuniary externalities) in the agricultural sector (Griliches, 1958; Schultz, 1953). These studies showed extensive benefits for users and consumers of new technologies. Later studies have confirmed such externalities, looking at innovations in manufacturing (Mansfield, 1965, 1995), as well as computer industry spillovers to the financial sector (Breshnahan, 1986). While most economists now regard pecuniary good externalities as a condition that may give rise to market failure, these externalities have been used in technology policy as an argument for subsidizing technology transfer and the take-up of, for example, ICT technologies (Klette et al., 2000; Sobel and Holcombe, 2001). (Gustafsson & Autio, 2011:822)

Technologies which deliver efficiency gains more broadly in the economy and spurs further technology development and cumulative innovation (Green & Scotchmer, 1995), has been conceptualized as general purpose technologies (Helpman & Trajtenberg, 1994). General purpose technologies (GPT) are technologies that contribute to economy more profoundly than technologies that has specific, limited usage (David, 2000; Brynolfsson & Hitt, 2000). The distinctive attributes of GPT are their pervasiveness, an innovation spawning effect, and scope for improvement (Helpman & Trajtenberg, 1994). They have properties of complementarity and are organized as clusters of technologies which are socially, politically and economically transformative (Bekar, Carlaw & Lipsey, 2018). GPT often times hold multiple purposes in applications (Bekar, Carlaw & Lipsey, 2018). Furthermore, GPT are an "evolving knowledge set" (Bekar, Carlaw & Lipsey, 2018).

Negative externalities from technologies
Negative externalities include external costs on the environmental from technologies, i.e. by creating damage to the environment, external costs of technologies on society, external costs on humans from technologies.

The system failure rationale

The second key rationale for government intervention and support in research, technology development and innovation is the systems failure rationale. The failure rationale has been conceptualized and studied substantially at the level of national, regional, and sectoral innovation systems. System failure rationales can be categorized into four main types: (1) Deficiencies in innovation infrastructure and institutional settings; (2) System-level inertia and lock-in mechanisms; and (3) Inhibited emergence of innovation and business ecosystems; and (4) Global innovation system coordination failures.

Deficiencies in innovation infrastructure and institutional settings

Innovation systems may fail to produce high innovation output because of deficient links between knowledge production and use and the difficulty in synchronizing activities among heterogeneous actors (Etzkowitz &Leydesdorff, 2000). Even though individual actors or functions in a given system may perform efficiently according to actor-level metrics, the system as a whole may perform sub-optimally, in the sense that its capacity to generate and exploit advances in knowledge is not commensurate with the level of output typically seen for a given level of resource investments. Thus, 'efficient' organizational-level processes may produce 'inefficient' performance at the system level (Gustafsson & Autio, 2011:823). Such inefficiencies may arise as asynchronous adaptation and development of innovation system constitutive elements. Relatedly, existing legal, regulatory and financial conditions for generating and diffusing innovation may also constrain firms from innovating (Edler et al., 2016). For example, the increasing use of digital technologies, software and platforms changes the value creation and capture logics in fundamental ways and current legislation may not be well suited to promote innovation in sectors.

System-level inertia and lock-in mechanisms

An important theme in the innovation systems literature concerns the inability of the system to dynamically evolve to embrace new productive opportunities, even if such opportunities were known to system participants. This inability is usually attributed to various sources of system inertia at sector and national levels. Inertia may arise, for example, from the system's inability to break free from established externalities, which prevents it from taking up new productive arrangements. This failure is usually termed as “lock-in” or “path-dependency” failure (Smith, 1997). Another important theme in research on innovation system dynamics focuses on the mode of innovative activity that the system locks into, in terms of the balance between exploration and exploitation (March, 1991). (Gustafsson & Autio, 2011:824)

The diffuse literature on ‘system failure’ suggests that, mainly due to structural and regulatory deficiencies and institutional inertia, the yield of R&D investments may be sub-optimal even in situations where R&D investments do happen. System-level inertia, thus, explains why actors embedded in the structure are disinclined to take up individual or coordinated action that would challenge or divert from the dominant structure. To overcome structural inertia, the constraining effect of the structure needs to be alleviated by changing the structure. Thus, the systems failure literature has been mostly focused on describing system-level inertia in relatively mature sectors, and has given less attention to the challenges arising from the nature of knowledge exploration and exploitation activities in emerging technological fields. (Gustafsson & Autio, 2011:824)

Inhibited emergence of innovation and business ecosystems

Two distinct mechanisms that inhibit emergence of innovation and business ecosystems can be specified: (1) *field-level relational mechanisms and inhibited emergence* (2) *impediments in productive social construction and structuration of technology*.

Field-level relational mechanisms and inhibited emergence

Emergence in novel technological fields are constrained due to the prevailing incumbency structure on sense-making and exploration. Three important field-level mechanisms generate such constraints. First, incumbents and established institutional structures tend to dominate learning and knowledge-creation processes, thereby crowding out learning and knowledge inputs by outsiders. Second, lack of legitimacy may prevent new entrants from participating effectively in experimentation around novel technological opportunities – engagement that would provide productive input to industrial change and the emergence of new industries. Third, established role expectations in innovation (e.g. the role of university actors or entrepreneurs) both shape and constrain learning processes themselves and may cause knowledge disconnects and asynchronicity between learning agents, especially when they follow institutionalized practices. Hence, learning and sense-making-driven institutional emergence becomes constrained, especially for disruptive technologies. (Gustafsson & Autio, 2011:824)

An efficient structuration and realignment of innovation systems requires unconstrained and institutionally disembodied collective experimentation. While actors are embedded within their respective institutional structures, third party actors and mediators who are able to facilitate and support this social adaptation process would advance institutional emergence in ways which institutionally embedded agency cannot. Rather than relying on the system’s own self-organizing capacity, and hence, on institutionally driven structuration processes, governments should be concerned with legitimating marginalized actors and institution building action to enable and advance institutional emergence. (Gustafsson & Autio, 2011:824)

Governments role as coordinator and facilitator is due to coordination problems that often arise in complex settings (Warwick, 2013), i.e. national, regional and sectoral innovation systems, and emergent innovation and business ecosystems. Complex settings easily suffer from insufficient exchange, interaction and cooperation (Woolthuis et al., 2005). Such insufficiencies can arise due to ambiguities, i.e. lack of clarity about who the partners are, complexities in arrangements as they are complicated and often incomplete, and dynamics to be accounted for, arising from the evolution of partners and external environment creating the need for adjustment (Huxham, 2003). Furthermore, collaboration takes time to emerges, what Huxham (2003) calls collaborative inertia and collaboration is not always spontaneous (Matt, Robin, & Wolff, 2012). As such there are system(ic) level failures and supportive structures in such settings to productively reorganize and adapt to technological change, especially when such technological change is more disruptive.

Also, when some vital component of the system is in need of improvement government intervention can be well argued, or when the capabilities of the actors that take part are not adequate to establish coordination (Edler & Fagerberg, 2017). Government as coordinator is further pronounced when there are needs for joined-up intervention from different policy domains i.e. in instances when established industries require technological renewal or the opening of an industry sector for increasing competition (Magro & Wilson, 2018).

The benefits of networking are many. Networking allows "risk sharing, obtaining access to new markets and technologies, speeding products to market, pooling complementary skills, safeguarding property rights when complete or contingent contracts are not possible, and acting as a key vehicle for obtaining access to external knowledge" (Pittaway, Robertson, Munir, Deneyer, & Neely, 2004:145). Empirical studies have exposed "that those firms which do not co-operate and which do not formally or informally exchange knowledge limit their knowledge base long term and ultimately reduce their ability to enter into exchange relationships."(Pittaway, Robertson, Munir, Deneyer, & Neely, 2004).

Impediments in productive social construction and structuration of technology
Cultural-cognitive limitations related to technology structuration and use. Emergence, self-organization, and productive evolution of communities of practice among and between autonomous actors in innovation structures thus become constrained (Gavetti and Levinthal, 2000). This constraint inhibits the development and formation of shared field-level expectations regarding market evolution, technological opportunities, and value propositions. The fragmented innovation and field structure constrain institutional experimentation, generation of externalities, and trajectory guidance. (Gustafsson & Autio, 2011:824)

Although individual organizations rarely possess sufficient legitimacy and capacity to facilitate the formation of communities of practice in situations of non-incremental change, government actors are better equipped in this regard, for several reasons. First, government controls many key institutional building blocks of innovation structures, for example, universities, national R&D laboratories and legislative bodies. Second, government also plays a central role in defining institutional mechanisms that bridge different actors within the innovation structure. Such institutional mechanisms include, for example, intellectual property rights law and the definition of the mandates of public sector agencies active in technology commercialization. These mechanisms can be levied upon to impose an institutional logic and governance structure that guides the structuration and conceptions of opportunities in the emerging field. Third, governments often possess the strong legitimacy and capacity to function as the game-setter for explorative and exploitative platforms (Cole, 1985). Fourth, from a welfare economics perspective, the government has an interest in enabling technological change. It also possesses the type of long-term stable economic resources that are required for exploration, negotiation, and reorganization of institutional structures in changing and emergent fields. These resources might also be used for compensating sunk costs of previously dominant institutional structures, as these adapt to new opportunities. Because of these four characteristics, governments are well equipped to facilitate the emergence and productive evolution of communities of practice within novel technological domains, especially during times of non-incremental change. (Gustafsson & Autio, 2011:824)

Global innovation system coordination failures
Recently researchers have put forth how failures currently addressed widely at the national, regional and sectoral innovation system level, also exists at the global level. However, the system failures at this level are again at least in part rather distinct from previous addresses system type failures. Such failures may include global policy coordination failure, resulting in overcapacities of products globally in rapidly developing technological fields, i.e. photovoltaic panels or resulting in trade disputes. Overall such coordination failures can hamper in several ways the progression of development of technological fields and markets. Such systemic failures arise from the different innovation system elements becoming complexly structured at an international level. When taking the global innovation system lens, Binz & Truffer (2017) have suggested to consider the externalities that support industry formation and innovation. To do this, four generic types of system resources could be considered: (1) knowledge; (2) market access; (3) financial investments; and (4) technology legitimacy (Binz & Truffer, 2017). These may each evolve in their own spatial configuration (Binz et al., 2016). Innovation and industrial policies at a national or regional level should then accordingly aim at reflecting the targeted industry's GIS configuration (Binz et al., 2017; Quitzow et al., 2017).

Policy outcome rationales: Benefits for firms, industries, regions, and the economy

There is today extensive evidence on the various economic benefits of investment in research, technology development and innovation from a societal perspective. The underlying economic attributes of technologies, technological change, innovation, and generation of new ideas have been shown to have profound positive economic effects at the macro societal level (i.e. Helpman, 1998; Jaffe et al., 2004; Romer, 2000; Klette, Moen, & Griliches, 2000), positive effects on innovation, entrepreneurial, and business ecosystem level, i.e. in knowledge development and diffusion, entrepreneurial experimentation, influence on the direction of search, market formation, development of positive external economies, legitimation and resource mobilization (i.e. Autio et al. 2014; Bleda & del Rio, 2013; Knockhaert et al., 2019; Peneder, 2016; Warwick, 2013), and positive effects on the level of firms and organization level (Becker, 2015; Ylhäinen et al., 2016; Also, individual studies see Vanino et al., 2019; Guo et al., 2016; Einiö, 2014). The distinctive character of technological knowledge and its tendency to spillover (generating externality benefits) from firms that invested in research, technology development, and innovation to other firms play a crucial role in modern growth theory (i.e. Aghion and Howitt, 2009). As such public investments in research, technology development and innovation is considered valuable as sharing the risk from a well-fare economic benefit perspective. The economic impacts and additionalities are discussed in-depth in part II.

Mission-oriented innovation policy rationales

Mission-oriented innovation policy, or also termed strategic innovation policy (Weber, & Rohracher, 2012) reasoning have increasingly entered into the innovation policy agenda. Mission oriented policy are “about direction – about concrete problems to be solved” (Kattel, & Mazzucato, 2018:789). Mission-oriented innovation policies are “problem specific, using innovations in multiple sectors to achieve concrete targets – whether for military purposes, or for achieving targets in areas such as energy (e.g. zero carbon emission) or health (e.g. eradicating cancer)” (Mazzucato & Semieniuk, 2017:30). Mission-oriented innovation policy has been further specified as including the “setting a purpose for public investments: “big science” meets “big problems” (Weinberg, 1967; Ergas, 1987)”, and for “creating conditions for new markets: enabling spill-overs from “big science” in form of new demand and supply (Mazzucato, 2017; Kuhlmann & Rip, 2018)” (Kattel & Mazzucato, 2018:789). We identify four mission-oriented policy rationales in our literature review: (1) grand and societal challenges; (2) responsible innovation; (3) demand-side innovation policy; and (4) public sector innovation.

Grand and societal challenges

The term “societal challenges” is used mostly synonymously with “grand challenges”, previously also conceptualized as ‘wicked problems’ (Rittel & Weber, 1973). The terms grand challenges and societal challenges were first introduced in 2007 as a new rationale to justify comprehensive coordination efforts within the European Research Area (European Commission, 2007). Grand challenges addresses problems and issues were the scale of stakes are substantial, the problems and issues are of supranational scope, they are urgent and require long term commitment to solve them, and were scale of effort is beyond single countries (Kallerud, et al., 2013). Such grand challenges are for example climate change, a decarbonized energy system (Rogge & Reichardt, 2016), sustainability transitions of socio-technical systems (Kivimaa & Kern, 2016; Schot & Steinmuller, 2018). aging society, and security. They require to be solved multi-objective policy, going beyond research and innovation policy, and international cooperation to find effective solutions (Leijten et al., 2012). Grand challenges bring attention to interdependencies and extensive overlap between societal and economic objectives and the need for policy to account for both. The innovation scope of grand challenges is as such different from previous identified in this report. The innovation scope of grand challenges aims for transformative innovations that radically change unsustainable current practices, responsible innovation that goes beyond profit and economic competitiveness to safeguard social and environmental goals, and social innovations for the public good (Owen, Macnaghten, & Stilgoe, 2012).

Responsible innovation

Responsible innovation (RI), also conceptualized under the broader definition of responsible research and innovation (RRI) have recently been brought up as a distinctive mission oriented goal innovation policy goal, as a distinct grand challenge, requiring specification and targeted emphasis in innovation policies (Stilgoe, Owen, & Macnaghten, 2013). Responsible innovation has also been depicted under the concepts of responsible development and responsible governance. Responsibility is a abroad term, aiming to capture the idea of the governance mode of innovation processes as "responsible processes as opposed to processes that are not supervised responsibly" (Burget, Bardone, & Pedaste, 2017:14). Responsibility in innovation processes have been suggested to incorporate active anticipation, reflexivity, inclusion, and responsiveness (Stilgoe, Owen, & Macnaghten, 2013). A recent specification and novel concept for addressing responsible innovation is distribution sensitive innovation policy (DSIP). It addresses the ways in which present innovation policies or absent innovation polices generate economic inequities for various groups and stakeholders in an industry and individuals in society. Distribution sensitive innovation policies have the aim to "increase growth while taking into account economic distribution" (Zehavi & Breznitz, 2017:327). Different types of such innovation policies have been suggested, including the supporting of traditional industries, innovation policies directed at a specific disadvantaged geographic areas or economic communities, targeting ascriptive groups, i.e., groups to which a person belongs by birth, such as women or ethnic group, and, innovation policies focusing on disadvantaged technology consumers (e.g., the disabled) (Zehavi & Breznitz, 2017).

Demand-side innovation policy

Demand-side innovation policy (Hicks, 2016) or also conceptualized as demand-oriented innovation policy (Edler & Gergohiou, 2007) and demand-driven innovation policy address "measures that orient the generation of knowledge towards demand issues in areas where more research is needed as well as towards the generation and the diffusion of innovations by stimulating demand for and by creating better conditions for the take-up of innovations (Breznitz et al., 2009)" (Kaiser & Kripp, 2010:2). Recently also creation of markets and the shaping of markets have been included as a specific demand innovation policy goal (i.e. Mazzucato, 2016) as in response to how "successful policies that have led to radical innovations have been more about market shaping and creating through direct and pervasive public financing, rather than market fixing" (Mazzucato & Semieniuk, 2017:24). Demand-side innovation policy is a policy intervention to address the innovation systems failure of inhibited emergence of innovation and business ecosystems (Gustafsson & Autio, 2011).

Public sector innovation

Public sector innovation takes place in regulated market environment which do not function efficiently, the market does not push actors to actively innovate in the same way as in industries were markets operate more according to perfect market competition. As such innovation is hampered, and not in the same way demanded. Further, the resources used in the public sector may include inefficiencies which could be address through innovation. Also, the quality of public service could be addressed through innovation generating pay back through economic efficiencies and social well-being (i.e. reduced costs of health care). As such there are multiple reasons for public sector innovation promotion that could address services, service delivery, administrative / organizational innovations, systemic innovations, policy innovations and conceptual innovations (Arundel, Block, & Ferguson, 2019).

Bibliography

Arrow, K. (1962a). Economic welfare and the allocation of resources for invention. In: Nelson, R. (Ed.), The Rate and Direction of Inventive Activity. Princeton University Press, New Jersey, 609–625.

Arrow, K. (1962b). The economic implications of learning by doing. Review of Economic Studies 29 (3), 155–173.

Arundel, A., Bloch, C., & Ferguson, B. (2019). Advancing innovation in the public sector – Aligning innovation measurement with policy goals. Research Policy, 48(3), 789–798.

Bekar, C., Carlaw, K., & Lipsey, R. (2018). General purpose technologies in theory, application and controversy: a review. Journal of Evolutionary Economics, 28(5), 1005–1033.

Binz, C. & Truffer, B. (2017). Global Innovation Systems – A conceptual framework for innovation dynamics in transnational contexts. Research Policy, 46(7), 1284–1298.

Burget, M., Bardone, E., & Pedaste, M. (2017). Definitions and conceptual dimensions of responsible research and innovation: a literature review. Science and engineering ethics, 23(1), 1–19.

Breshnahan, T.F. (1986). Measuring the spillovers from technical advance: mainframe computers in financal services. American Economic Review 76, 742–755.

Brynjolfsson, E. & Hitt, L. M. (2000). Beyond computation: Information technology, organizational transformation and business performance. Journal of Economic perspectives, 14(4), 23–48.

Doern, G. B. & Stoney, C. (Eds.) (2009). Research and innovation policy: Changing federal government-university relations. University of Toronto Press.

Edler, J. (2016), 'The Impact of Policy Measures to Stimulate Private Demand for Innovation', in J. Edler, P. Cunningham, A. Gök, and P. Shapira (eds), Handbook of Innovation Policy Impact, Cheltenham, Edward Elgar, 318–354.

Edler, J. & Fagerberg, J. (2017). Innovation policy-what, why, and how. Oxford Review of Economic Policy, 33(1), 2–23.

Edler, J. & Georghiou, L. (2007). Public procurement and innovation – Resurrecting the demand side. Research policy, 36(7), 949-963.

Edler, J., Gök, A., Cunningham, P., & Shapira, P. (2016). Introduction – Making sense of innovation policy. In Handbook of Innovation Policy Impact. Edward Elgar Publishing.

Ergas, H. (1987). Does technology policy matter. In Guile, B.R. & Brooks, H. (Eds.). Technology and global industry: Companies and nations in the world economy. National Academy Press, Washington, DC.

Etzkowitz, H. Leydesdorff, L. (2000). The dynamics of innovation: from national systems and "Mode 2" to a triple helix of university-industry-government relations. Research Policy 29, 109–123.

Fisher, E. & Rip, A. (2013). Responsible innovation: Multi-level dynamics and soft intervention practices. Responsible innovation, 165–183.

Flink, T. & Kaldewey, D. (2018). The new production of legitimacy- STI policy discourses beyond the contract metaphor. Research Policy, 47(1), 14–22.

Griliches, Z. (1992). The search for R&D spillovers. Scandinavian Journal of Economics 94, 29–47.

Gustafsson, R. & Autio, E. (2011). A failure trichotomy in knowledge exploration and exploitation. Research Policy, 40(6), 819–831.

Green, J. R. & Scotchmer, S. (1995). On the division of profit in sequential innovation. The RAND Journal of Economics, 20–33.

Helpman, E. & Trajtenberg, M. (1994). A time to sow and a time to reap: Growth based on general purpose technologies (No. w4854). National Bureau of Economic Research.

Huxham, C. (2003). Theorizing Collaborative Practice. Public Management Review, 5(3), 401–423.

Janeway, W. (2012). Doing Capitalism in the Innovation Economy, Cambridge, Cambridge University Press

Kaiser, R. & Kripp, M. (2010). Demand-orientation in national systems of innovation – a critical review of current European innovation policy concepts. In DRUID Summer Conference.

Kallerud, E., Amanatidou, E., Upham, P., Nieminen, M., Klitkou, A., Olsen, D. S., & Scordato, L. (2013). Dimensions of research and innovation policies to address grand and global challenges. NIFU Working Paper, 13.

Kattel, R. & Mazzucato, M. (2018). Mission-oriented innovation policy and dynamic capabilities in the public sector. Industrial & Corporate Change, 27(5).

Kivimaa, P. & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Research Policy, 45(1), 205–217.

Klette, J., Moen, J., Griliches, Z. (2000). Do subsidies to commercial R&D reduce market failures? microeconometric evaluation studies. Research Policy 29, 471–495.

Kline, S.J. & Rosenberg, N. (1986). An overview of innovation. The positive sum strategy: Harnessing technology for economic growth. The National Academy of Science, USA.

Kuhlmann, S. & Rip, A. (2018). Next-generation innovation policy and grand challenges. Science and public policy, 45(4), 448–454.

Lazonick, W. & Mazzucato, M. (2013). The risk-reward nexus in the innovation-inequality relationship: who takes the risks? Who gets the rewards?. Industrial and Corporate Change, 22(4), 1093–1128.

Magro, E. & Wilson, J.R. (2019). Policy-mix evaluation Governance challenges from new place-based innovation policies. Research policy, 48(10), 103612.

Mansfield, E. (1965). Rates of return from industrial R&D. American Economic Review 55, 863–873.

Mansfield, E. (1995). Academic research underlying industrial innovations: sources, characteristics, and financing. The Review of Economics and Statistics 77 (1), 55–65.

March, J.G. (1991). Exploration and exploitation in organizational learning. Organization Science 2 (1), 71–87.

Martin, B.R. (2016). R&D policy instruments – A critical review of what we do and don't know. Industry and Innovation, 23(2), 157–176.

Matt, M., Robin, S., & Wolff, S. (2012). The influence of public programs on inter-firm R&D collaboration strategies: project-level evidence from EU FP5 and FP6. The Journal of Technology Transfer, 37(6), 885–916.

Mazzucato, M. (2011). The entrepreneurial state. Soundings, 49(49), 131–142.

Mazzucato, M. (2013). Financing innovation: creative destruction vs. destructive creation. Industrial and Corporate Change, 22(4), 851–867.

Mazzucato, M. & Semieniuk, G. (2017). Public financing of innovation- new questions. Oxford Review of Economic Policy, 33(1), 24–48.

Mazzucato, M. & Tancioni, M. (2012). R&D, patents and stock return volatility. Journal of Evolutionary Economics, 22(4), 811–832.

Metcalf, S. (1995). The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives/P. Stoneman ed. Handbook of the Economics of Innovation and Technological Changes.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. Science and public policy, 39(6), 751–760.

Pavitt, K. (1987). The objectives of technology policy. Science and Public Policy, 14(4), 182–188.

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and innovation- a systematic review of the evidence. International journal of Management Reviews, 5(3–4), 137–168.

Rittel, H.W. & Webber, M.M. (1974). Wicked problems. Man-made Futures, 26(1), 272–280.

Romer, P. M. (1990). Endogenous technological change. Journal of Political Economy, 98(5, Part 2), 71–102.

Rogge, K.S. & Reichardt, K. (2016). Policy mixes for sustainability transitions – An extended concept and framework for analysis. Research Policy, 45(8), 1620–1635.

Samuelson, P. A. (1954). The pure theory of public expenditure. The Review of Economics and Statistics, 387–389.

Schot, J. & Steinmueller, W.E. (2018). Three frames for innovation policy – R&D, systems of innovation and transformative change. Research Policy, 47(9), 1554–1567.

Schultz, T.W. (1953). The Economic Organization of Agriculture. McGraw-Hill, New York.

Smith, K. (1997). Economic infrastructures and innovation systems. In: Edquist, C. (Ed.), Systems of Innovation: Technologies, Institutions and Organizations. Pinter, London, 86–100.

Sobel, R.S. Holcombe, R.G. (2001). The unanimous voting rule is not the political equivalent to market exchange. Public Choice 106 (3/4), 233–242.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. Research Policy, 42(9), 1568–1580.

Weber, K.M. & Rohracher, H. (2012). Legitimizing research technology and innovation policies for transformative change Combining insights from innovation systems and multi-level perspective in a comprehensive failures framework. Research Policy, 41(6), 1037–1047.

Weinberg, A.M. (1968). Reflections on big science. American Journal of Physics, 36(1), 65–66.

Woolthuis, R.K., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. Technovation, 25(6), 609–619.

Zehavi, A. & Breznitz, D. (2017). Distribution sensitive innovation policies- Conceptualization and empirical examples. Research Policy, 46(1), 327–336.

Part II. Innovation promotion impact

In the second part of the report, we will summarize recent empirical evidence from research literature, and discuss our synthesis in relation to the government rationale in engaging in innovation promotion. We will highlight several key issues that intersect between innovation promotion impact evidence, and rationales and justification for government intervention. This part of the report ends by discussing the implications to research and policy practice. The general conclusion is that holistic focus to policy practice and impact evaluation is needed.

Impact literature overview

The impact of governmental innovation promotion has been a lasting interest of researchers and policy evaluators. There exist a general consensus that technology is the key source for productivity and economic growth (e.g. Williamson, 2002; Griliches, 1979; Solow, 1957), and in the process of technological advancements investments in research and innovation activities have been seen as paramount (van Elk et al., 2019; Laukkanen & Maliranta, 2019; European Commission, 2017). However, due to the reasons highlighted in the report – particularly market failure rationale and system failure rationale – private enterprises do not produce socially optimal level of investments on R&D and innovation activities (Levin et al., 1987; Arrow, 1951; 1972). From impact perspective, this justifies government intervention on markets, particularly on innovation activities of private enterprises, and the impact of the intervening policies has been seen on average more positive than negative (e.g. Ylhäinen et al., 2016; Becker, 2015). Thus, the debate on public innovation promotion impact focuses more on effectiveness of intervention types (e.g. crowding-out or not), and the proper role of government in this sphere[1], namely either only supporting private actors with limited intervention scope, or taking more an active role in making choices and 'creating markets' with proactive policies to solve 'grand challenges' and foster advancement of nascent technological fields and radical innovations (e.g. Torregrosa-Hetland et al., 2019; Mazzucato, 2016). Considering the latter from these perspectives, there has been recently re-emerged salience of 'mission-oriented' innovation policies (OECD, 2017; European Commission, 2017; Mazzucato, 2016), i.e. solving and targeting economically or societally important issues and challenges with innovation policies (Flink & Kaldewey, 2018; Fagerberg, 2017). This gradually re-shifting policy focus is visible also in the Finnish policy context with a call for new national and cross-administrative vision to solve economic needs and tackle societal challenges with innovation promotion (See OECD, 2017). To then ensure that the expectations of these policies will be fulfilled, there is ever increasing need to improve the impact evaluations methodology and continue in tandem with the work of constantly increasing our understanding of the real policy impact. For instance, if the public policy targets extend beyond pure R&D input additionalities, there is also need to include the broader goals in the policy evaluation framework in order to evaluate and justify the policies.

Consequently, in this second part of the report, the focus will be on recent research trends and empirical findings on innovation promotion impact in relation to the rational for government to engage in innovation promotion. Overall, there exist extensive literature focusing on the impact of public innovation promotion with different study contexts, samples, policy instruments, methodologies, and outcome variables (e.g. Aiello et al., 2019; Edler & Fagerberg, 2017; Becker, 2015). For instance, Edler & Fagerberg (2017: 13–15; Also, Cunningham, 2016) mention that there exist over 700 academic studies and policy evaluations on the impact of several policy instruments[2]. Due to the extant large literature both internationally (Edler & Fagerberg, 2017; Dimos & Pugh, 2016; Becker, 2015; Zuniga-Vicente et al., 2014; David et al., 2000; Klette et al., 2000) and in the Finnish context[3] (Torregrosa-Hetland et al., 2019; Ylhäinen et al., 2016; Autio & Rannikko, 2016; Takalo et al., 2017; Einiö, 2014; Takalo et al., 2013; Autio et al., 2008; Hyytinen & Toivanen, 2005), there is no need to review this whole body of literature again. For instance, Ylhäinen et al. (2016) provide extensive microeconometric literature review both Finnish and international impact studies focusing on public subsidy support on private R&D, and discuss several conclusions from their review for both policy practice and research methodology.

Instead, by reviewing recent research literature, the more detailed focus of the second part of the report is to highlight key current issues with regards to innovation promotion evaluations and impacts, while linking these considerations to the rationales of innovation promotion and justifications of public intervention. In innovation promotion, the most commonly used policy instruments are direct support to firm R&D and innovation activities in form of direct financial support (subsidies) and indirect support through tax credits (e.g. Becker, 2015), and policies to foster and facilitate collaborations (e.g. Torregrosa-Hetland et al., 2019; Veugelers, 2015). The main focus of the report will be on the direct support instruments, as these are mostly used and found in the evaluation studies, but in addition other interesting recent studies on innovation promotion outcomes will also be discussed. For instance, these include macro-perspectives that do not delimit the analysis scope to certain policy instruments (val Elk et al., 2109; Torregrosa-Hetland et al., 2019; Vanino et al., 2019).

To summarize, extant studies show that in general the benefits of innovation promotion are positive (e.g. European Commission, 2017; Becker, 2015). More in detail, tax credit policies have been seen fostering positive effect on firm R&D input (Hall & Van Reenen, 2000; Becker, 2015). Also, direct R&D subsidies provide several positive additionality effects, mainly R&D intensity or expenditure additionalities, but studies are still divided on how much the direct financial support crowds-out private investments to R&D, and does the support translate into long-lasting innovation activities as well as important innovation outputs. In addition, there is tentative evidence on positive impact of innovation promotion on broader policy goals (Torregrosa-Hetland et al., 2019; Vanino et al., 2019) that lend support to justify the "mission-oriented" innovation policies in terms of enabling broader renewal of economies and in fostering societal welfare. Overall, there are then some mixed results and heterogeneity, mostly due to different research designs (e.g. Zuniga-Vicente et al., 2014). This means that the main issues that remains is how to evaluate the impact of innovation promotion holistically and lognitudinally, while acknowledging the important segment differences and heterogeneity with regards to policy instruments, national contexts, firms, industries, and type of innovations and technologies.

Recent impact research findings

In general, the economic impact of research and innovation to productivity and economic growth are extensive. For instance, recent policy report from European Commission (2017) concludes that when broadly defined research and innovations have accounted for two thirds of economic growth and productivity in Europe (between 1995–2007), or more narrowly between 2000–2013 around 30% of labor productivity growth in Finland[4] (European Commission, 2017: 3). These effect are fostered by private firm investments on R&D and innovation activities, from which there is evidence of net positive benefits for firms. In this context, public innovation promotion has been seen also having positive impact on firm private R&D investments (European Commission, 2017: 4–5). In addition, when contrasted with other forms of government subsidies to private sector, innovation promotion is far the most efficient and justified policy instrument (Laukkanen & Maliranta, 2019).

Based on the research literature[5], we have compressed the impact of innovation promotion policy intervention to two broad categories. First, we review the recent findings on additionalities (input, output, behavior). In this review, we focus on both review-articles to have the broad view on the topic, and then evaluate recent empirical studies using additionality measurement. Secondly, we discuss latest studies that focus on broader impact assessment than additionalities e.g. including macro-economic and long-term impacts.

Additionalities

This report utilizes the terminology from additionality evaluation framework[6] (e.g. See Hyvärinen & Rautiainen, 2006). This analysis framework typically views innovation promotion bringing 'additionalities' on innovation inputs (R&D expenditure or intensity), behavior (innovation process and activities), and outputs (innovation results and direct effects to firms). More in detail, behavioral additionality refers to improved R&D project characteristics (e.g. scale, risk and quality), capabilities (e.g. collaborations and innovation management), and competences (e.g. human capital and strategic choices). Output additionality refers to two broad outputs of R&D processes, namely innovation results (e.g. publications, patents, prototypes, new products and services) and direct firm effects (e.g. turnover, value added, exports, employment, and productivity) (Hyvärinen & Rautiainen, 2006; Also Autio et al., 2008).

Overview

Recent literature reviews and policy evaluations utilizing the additionality evaluation framework point out positive effects from innovation promotion financial instruments (funding, tax incentives) on private R&D activities and innovations (e.g. Laukkanen & Maliranta, 2019; European Commission, 2017; Ylhäinen et al., 2016; Becker, 2015; Zuniga-Vicente et al., 2014). Particularly, the literature on input additionalities is extensive and generally supports the statement of finding positive results from public financial support on firm R&D and innovation activities (See reviews David et al., 2000; Klette et al., 2000; Zuniga-Vicente et al., 2014; Becker, 2015). For instance, this makes Becker (2015) to conclude in her review article that "*the general conclusion from the post-2000 empirical evidence must be that public R&D subsidies succeed in significantly stimulating private R&D investment–*". Studies focusing on output additionalities have been less frequent, utilize multiple different impact output measures (e.g. patents, exports, sales), and have some mixed findings on how innovation promotion has an effect on a particular output additionality (See individual studies Aiello et al., 2019; Hünermund & Czarnitzki, 2019; Freel et al., 2019; Beck et al., 2016; Bronzini & Piselli, 2016; Bérubé & Mohnen, 2009).

More in detail, recent literature review conducted by Ylhäinen et al. (2016) supports the general tendencies highlighted by the research literature. The authors review large body of literature prior 2017 and summarize the results of studies concerning international contexts and Finland to three categories (positive impact, negative impact, and unclear/not significant[7]) both in general level and with regards to specific outcome variables (R&D investments, labor, patents, productivity). In general level, they conclude that the studies from international context show that the impact of subsidies to private R&D activities are mostly positive or unclear rather than being significantly negative. Also, they specially find that R&D subsidies generating positive or unclear input additionality (measured by R&D expenditure or insensitivity) has been found in over 90% of international studies, whereas the amount of negative effects remain under 10% (Ylhäinen et al., 2016: 24–26).

From the literature reviews, Becker (2015) finds support from the empirical studies for positive effects for both tax credits and public R&D subsidies on private R&D investments. Concerning R&D subsidies, the effect is heterogeneous and most effective on small firms with financial constraints. The author also argues that tax credits for stimulating private R&D investments are more positive than prior studies have assumed, and that the crowding-out effect is weaker, or non-existent, than previously thought. Becker (2015: 935–936) concludes that government funding schemas seem to be effective, but should be more targeted e.g. on smaller firms instead of large firms, and different policy instruments should be coordinated to maximize the positive impacts.

In addition, Becker (2015) offers summary of spillovers from university research on firm R&D and impact of R&D cooperation on incentivizing private R&D spending, and concludes that both of these effects are positive. First, she finds that regional R&D policies facilitate formation of regional clusters of university research and firm R&D to exploit agglomeration economies, and supporting university research has positive spillovers to local firm R&D spending. Also, there is evidence from studies that closeness to university research is important in high-technology sectors, concluding that literature implies that human capital investments increase private R&D. Secondly, Becker (2015: 925–932) finds that facilitating R&D cooperation increases private R&D, and more particularly these policy instruments "– include provision of direct funding for various forms of R&D cooperation and provision of appropriate intellectual property protection mechanisms" (Becker, 2015: 932). There is also evidence that geographic proximity helps to foster cooperation, which supports the rationale for supporting regional clusters of R&D activities.

In their meta-analysis of 77 impact studies, Zuniga-Vicente et al. (2014) find support for the additionality hypothesis, but also opposite effects are present (substitution and negligible effects). They conclude that the empirical evidence is still mixed and inconclusive, which can be due to the methodological and study design heterogeneity, such as sampling, subsidy programs, contextual differences and theoretical frameworks utilized. Dimos & Pugh (2016) do not find strong evidence for the additionality effects in their meta-analysis, but find evidence to conclude to reject the crowding-out effect.

Moreover, input additionality considerations include typically also discussion of crowding-out effect (Becker, 2015), because policy makers need to consider and evaluate opportunity costs when using public funds. In this line of reasoning, counterfactual considerations are also utilized, particularly does the public funding suppress private funding for R&D that would have been invested without the public intervention ("crowding-out")[8]. The recent evidence seems to suggest that crowding-out effects are perhaps overestimated (Marino et al. 2016; Becker, 2015) or crowding-out hypothesis cannot be supported based on the evidence (Choi & Lee, 2017; Dimos & Pugh, 2016). Additionally, Becker (2015) suggest that behind the overestimation are methodological shortcomings, and new econometric techniques enable to get more precise understanding of the phenomenon leading to more valid estimates. For instance, new techniques allow better control for selection effect, i.e. firms which would have undertaken R&D regardless of support, which could have caused overestimation of crowding-out prior controlling the selection effect.

Input additionality

Besides the recent literature reviews on additionalities, there has been new empirical evidence for the additionality effects. In this section, we will consider studies generating input additionalities, particularly direct subsidy or tax credit effects (Aiello et al., 2019; Choi & Lee, 2017; Beck et al., 2016; Dechezleprêtre et al., 2016; Marino et al., 2016; Rao, 2016; Beck et al., 2016; Bronzini & Iachini, 2014).

Aiello et al. (2019) utilize a sample of Italian manufacturing firms (1634 manufacturing SMEs, R&D performed during period 2001–2003) and control for the selection effect with propensity score matching. They find strong support for input additionality (complementary for firm R&D spending), but do not find effects on output additionality measured by patents. Compared with firms not receiving public support, the supported firms had lower levels of patents. Lastly, they compare tax credits with subsidies, and find subsidies pushing R&D input additionality more, but leading to decreasing levels of patents. Marino et al. (2016) do not find evidence of either additionality or crowding-out effects with a sample of French firms between 1993–2009. Bronzini & Iachini (2014) do not find evidence of input additionality on large firms in the context of Northern Italy, but when separating the effects between large and smaller firms of the subsidy program, they find evidence that smaller firms increased their R&D investments substantially. Lastly, Beck et al. (2016) find evidence with a Swiss innovation survey data that subsidies lead to increased input additionality.

Choi & Lee (2017) provide comprehensive and recent evidence on input additionality, using data from Korean pharmaceutical industry (222 firms, 844 observations from R&D surveys between 1994–1996 and 1998–2002), with their study of effects of public R&D subsidies on private R&D investments. They find that public support stimulated rather than crowded out R&D activities of small venture firms, concluding that this intervention type helped to address underinvestment failure among private firms on R&D. However, even though they find this as an evidence of public funding expanding knowledge base with the expanded R&D programs, they do not find strong support that the treated firms would have expanded to novel product R&D activities.

Working paper by Dechezleprêtre et al. (2016) use regression discontinuity design for the selection effect control to study treated and non-treated firms (threshold) on the effect of tax subsidies in the UK with tax administration data. They find positive economic effects of tax change on R&D and patents, concluding that total business R&D would have been 10% lower without the tax credit scheme. Rao (2016) uses corporate tax return data (IRS) from the United States and studies effects of tax credits (elasticity) for R&D expenditure. The author estimates that in the short run 10% reduction in the user cost translates into 20% increased R&D spending in comparison to sales (research intensity). In the long run, the study finds some adjustment costs, but firms increase spending over time, albeit small and young firms can reverse the increased spending in the long term. Component analysis of the increased spending imply that most of the increase is by research wages and supplies.

Output additionality

Recently, there has been also several studies that provide empirical evidence for output additionalities[9]. We will discuss these in terms of the outcome variables used, namely patents and innovation output (Aiello et al., 2019; Bronzini & Piselli, 2016; Guo et al., 2016), sales, employment and growth (Hünermund & Czarnitzki, 2019; Einiö, 2014;), exports (Freel et al., 2019), long and short term growth (Vanino et al., 2019; Autio & Rannikko, 2016), and innovation performance in terms of ratio of new product sales (Beck et al., 2016) or novel technologies (Wirsich et al., 2016).

Regarding patents, on one hand, Aiello et al. (2019) find no evidence for increase in patents with their Italian manufacturing industry study, but actually find lower patenting levels among publicly funded firms. Bronzini & Piselli (2016) use also sample of Italian firms under specific subsidy program, and find evidence of increase patents due to the government support. This results resonates with the study by Guo et al. (2016) that examine one of the largest R&D support program for SMEs in China. They measure innovation activity output by number of patents, but also utilize in the measurement of innovation output sales from new products and export. Overall, with controls for selection effects (propensity score matching), they find strong evidence for higher innovation activities among firms supported by the program.

There are also some mixed results within studies examining effects of innovation promotion on sales or employment. For instance, Hünermund & Czarnitzki (2019) study largest pan-European subsidy program for SMEs, and find no average effect on sales growth or job creation. However, when considering the possible heterogeneity in the effect, they find positive effects on high-ranked project by firms in comparison with low-ranked firm projects. Comparing the results to studies from Finnish context, Einiö (2014) finds positive effects on both employment and sales as well as inceased R&D investments from public subsidies when aggregated together with regional funding support.

Freel et al. (2019) focus how policy intervention on innovations lead to changing export behavior among German SMEs. The aim of the study is to expand the impacts beyond the typically measures of input additionality and patents as output additionality. They make three important findings: First, they find no significant associations innovations and new exports. Second, however, they find that innovation policies positively have an effect on export persistence and growth. Thirdly, considering the export growth, there is evidence of positive relationship between new product innovations and increased revenues from exporting. They conclude that these lend support for the link between new innovations driving exports, even though the results might be influenced by the specifics of the support program, focusing on smaller grants and with lower levels of technology ambition, in which the innovations are already near market and utilize already established competences.

Vanino et al. (2019) seek to tackle the issue of focusing only single policy instruments and programs in impact evaluation studies by conducting a comprehensive analysis of UK Research Council's public support for R&D and innovations and performance of firms. In their analysis, they utilize funding data between 2004–2016 by all UK Research Council's funding. For causal inference, they apply propensity score matching to compare firms who participated and did not participate to the UK support programs. They find that the supported firms grew approximately 6% faster in the short term and 22% faster in the long term in comparison with the control firms. Furthermore, they also discovered some heterogeneity with their average results: The effects are stronger in the most R&D intensive regions and industries, and among smaller and less productive firms. Also, the positive impacts of public R&D funded projects are important especially when collaborating with domestic and industrial partners. They conclude that public support has strong positive impact on firm growth both in short and longer terms, as well as their claiming that their results offer comprehensive support that innovation promotion is beneficial for private R&D and innovations. Resonating with these, Autio & Rannikko (2016) focus on single policy program. They control for the selection effect, and find that firms participating in a high-growth entrepreneurship program doubled their growth rates in comparison with the control firms.

Lastly, Beck et al. (2016) study effectiveness of innovation promotion in the Swiss context between 1999–2011. Their dependent variable for innovation performance is divided into two components: Radical innovations as share of sales (percentage) of newly introduced products, and incremental innovations as share of sales (percentage) of substantially improved products. They find evidence that the public subsidy support is significant for the radical innovation performance, whereas there was no effect on the incremental innovations. They also find that privately financed R&D has an effect on both of the innovation performance variables. However, there is no evidence that policies induce more collaborations among firms. Also, Wirsich et al. (2016) analyze university-industry collaborations with longitudinal patent-data and joint publications of 318 technology firms from S&P index between 1985–2007. They find that the collaborations have positive effect on new technology field discovery defined as exploration of new technologies, or novel combinations of existing technologies.

Behavioral additionality ('Second-order additionality')

There is also recent empirical evidence of some indirect behavioral additionalities, even though the empirical investigations to the topic have been scant (e.g. Clarysse et al. 2009; Autio et al., 2008)[10]. Earlier study in this area includes for instance Antonioli et al. (2012), who find that publicly supported firms in a specific region did not increase cooperation outside the region, but instead upgraded their competences ('cognitive capacity adding'). However, Beck et al. (2016) study could be viewed exception to this as their study is between output and behavioral additionalities. Although their main focus is on innovation performance outcomes, they find that public innovation promotion has impact on radical innovations performance ('riskier projects'). However, they do not directly discuss the change in firm behavior. Related to the study, Mulligan et al. (2019) evaluate whether mix of subsidies from regional, national and EU levels lead to higher proportion of engaging in innovation activities (Radical, incremental, process, organizational) in the firm level. They find that all the subsidy sources stimulate firm-level innovations, but particularly EU-level subsidies have highest effect on the likelihood to engage in radical innovations (in their terms also riskier projects), whereas regional and national subsidies have higher effects on incremental or organizational innovations.

Lastly, Wanzenböck et al. (2013) study how firm characteristics influence behavioral additionality with sample of 155 Austrian firms in transportation sector. They find important firm heterogeneity in their results: Young, small and technologically specialized firms have higher probability in realizing behavioral additionalities. Thus, they conclude that R&D subsidies should be directed more, from additionality perspective, to small and technologically specialized firms that have lower levels of R&D experience. Also, Knockhaert et al. (2019)[11] study firm participation to innovations ecosystems with sample of 473 Finnish firms (312 participated in an ecosystem). Their findings include (1) organizational interdependence and output additionality is mediated by behavioral additionality, and (2) 'internalizing' ecosystem with appointing members from the ecosystem to board of directors renders the effect between behavioral and output additionalities stronger. Also, Radicic et al. (2018) study how public support for innovation affects cooperation with sample of 312 SMEs from eight regions in the EU (questionnaire data; incremental innovations). They do not find evidence that the public support affects cooperation between competitors, find only marginal evidence on increased cooperation between customers and suppliers, and find evidence of strong increased cooperation with public or private knowledge providers.

Beyond additionalities

Macro-level evaluations

The main bulk of the innovation promotion impact research focuses on additionalities (Zuniga-Vicente et al., 2014; Becker, 2015; David et al., 2000; Klette et al., 2000). However, the objectives and justification for innovation promotion extends beyond the outcomes measured in the additionality framework. This underscores the need for extend impact evaluations beyond additionality framework (e.g. Ylhäinen et al., 2016; Takalo et al., 2017).

Interesting addition to the recent impact studies has been a study by Torregrosa-Hetland et al. (2019) in which the authors focus on macro-level impacts from public innovation funding. They use a novel dataset based on Literature Based Innovation Output method[12] that includes around 6700 significant innovations in Finland and Sweden between 1970–2013. They find that large amount of introduced and significant innovations in both countries have been publicly funded: In Finland, they estimate from significant innovations 35–55% have been publicly funded, and that 25–65% of significant innovations have been introduced with collaboration with public research. This contrast to many prior studies as they focus on macro-level (national) spread of publicly stimulated significant innovations. Thus, their longitudinal approach goes beyond usual additionality focuses on impacts of firm's innovation activities (e.g. input additionality). Lastly, the authors argue that their results lend tentative support to the claims of role of state in supporting private innovations, and particularly the central role of government intervention in facilitating radical innovations (Mazzucato, 2016; 2013).

Other recent macro-economic and longitudinal study is by van Elk et al. (2019) who evaluate publicly funded R&D investments[13] between 1963–2011 in 22 OECD countries. They use three different production

function models (Cobb-Douglas, translog models, augmented models) to estimate public R&D investment association to GDP and total factor productivity (TFP). Their estimates from these models show broad range of results (including insignificant results Cobb-Douglas model), and thus conclude that public R&D investments do not automatically "foster" GDP and TFP growth. However, the coefficient suggest that these results depend on the particular national context in question, and the results they provide are cross-country averages. They conclude that there should be caution to make causal claims of these results, and the results do not measure any "broader societal" impacts. Lastly, they state that they cannot divide the country-level public sector performed R&D into more specific components, which could be interesting for uncovering more in detail the heterogeneity between public sector conducted R&D activities and complex mechanisms that exist within this sphere.

Takalo et al. (2017) conduct counterfactual analysis that includes considerations to the opportunity costs with economic welfare analysis. They find that both R&D subsidies and tax benefits generate higher levels of R&D investments and spillovers than the counterfactual state in which there would be none. However, these do not change the participation rate to R&D within firms, and opportunity costs analysis for public funding shows that economic welfare is not increased significantly. With regards to this study, the earlier study from Takalo et al. (2013) find significant societal benefits from the public R&D funding and that the welfare is higher than the opportunity cost of using public fund, i.e. program benefits exceed opportunity costs of the funding.

Lastly, there has been also discussion that innovation promotion impact evaluation should consider policies in conjuncture (e.g. Kivimaa & Kern, 2015), instead of focusing only on individual programs and subsidies. Mulligan et al. (2019) study how the policy mix influence the subsidy estimation. They find that not controlling for different subsidies from different levels (EU, national, regional) leads to underestimation of the additionality effect of single subsidy source (additionality under-estimation of 3%). Furthermore, they compare firms that did not receive any subsidies to firms receiving mix of subsidies from national and EU levels, and find that received firms receiving the 'subsidy mix' are 25% more likely to engage in radical innovations. Also, this is higher than firms receiving subsidies only from national (12,76%) or EU (16,41%) sources.

Innovation promotion impact and rationales

In this section, we will discuss the implications from the recent impact research to the innovation promotion rationales and policy practice. We will consider these more in detail with three categories in which impact evaluation research and evidence intersects with the innovation promotion rationales: Contextual sensitivity, broader targets and measurements, and policy mix.

Taking context seriously: Policy context is not only 'contextual idiosyncrasy'

Innovation promotion policies are embedded to wider technological, societal and economic environments. Then, although the evaluation techniques aim to'isolate' the effects of specific policy interventions (ceteris paribus), there are some difficulties to fully detach the effects of policies from the broader context. These contextual particularities can influence both the estimates from impact evaluation research (confounders), and establish, in part, justifications for government interventions. Particularly, it is evident in entrepreneurship and innovation ecosystems -literatures that context matters (e.g. Autio et al., 2014), and this contextual "sensitivity" is becoming increasingly relevant for innovation promotion research literature (e.g. Edler & Fagerberg, 2017; Flanagan & Uyarra, 2016). This is shown by the research literature in which the external validity of studies evaluating individual policies in a particular national, industry or technological context has been acknowledged (e.g. Edler & Fagerberg, 2017).

The question with external validity is how much it is possible to infer and generalize from a study conducted in a particular context, whether it would be country, industry, policy or technology. Then, for research that seeks to estimate the real effects of individual policies or mix of policies, the influence of context (industry, technology, national) needs to be controlled, or the boundary conditions of a particular research acknowledged. For instance, Edler & Fagerberg (2017) stress the importance of contextual sensitivity: They explain that same policy instruments have been found to have very different outcomes in different national context (See also Cunningham et al., 2016). These considerations are also supported by the macro-economic results from van Elk et al. (2019), who explicitly stress the importance of national context in evaluating publicly conducted R&D impacts. They state that "– relationship between publicly performed R&D and economic performance is highly country-specific, and that only models that allow for heterogeneity across countries provide positive and statistically significant estimates of the rates of return" (van Elk et al., 2019: 77).

Furthermore, for policy rationale there might exist contextual factors that justify that certain policies exist at a particular context, would it be the regional and national levels, or in some industries or business ecosystems. For instance, in his working paper Veugelers (2015) analyses which sort of policy instruments are used in different European countries, and finds surprisingly similar policy mixes throughout countries, despite of differences in innovation capabilities and outcomes. He concludes to take closer look of these policy mixes in each national context in relation to each countries capacities and capabilities. Hud & Hussinger (2015) also take contextual factors into account in their study of public R&D support during financial crises, and find some positive effects from the public support during the crises. In addition, these contextual issues can include type of frontier research rationales highlighted by Flink & Kaldewey (2018) or more in general level rationales to solve system-level interties or advance emergence of novel technology regimes, industries or ecosystems (Warwick, 2013; Peneder, 2016), in which the rationales for intervention can be contingent on particular contextual factors.

Lastly, taking context seriously can also indicate cross-national considerations. In global economy, the locus of innovation activities and R&D are becoming more and more cross-border. For instance, recent report on the internationalization of R&D activities in Finland round that between 2008–2017 the share of abroad R&D has been rising, and currently around 14–25% of Finnish firm R&D are done outside the country (Ali-Yrkkö & Pajarinen, 2019). Furthermore, national level indicators are not well-equipped to investigate innovation outputs (Janger et al., 2017) and this makes still our considerations of impacts on national level macro-economic variables weak (Torregrosa-Hetland et al., 2019).

Impact measurement beyond additionalities: Broader 'missions' in policy justification

The main justification for innovation promotion lies in the positive externalities that the additionality framework does not directly measure (Ylhäinen et al., 2016; See also Takalo et al., 2017), and these effects are in general harder to estimate (e.g. Edler & Fagerberg, 2017). Particularly, innovation policies aim for increased welfare (economically, see Takalo et al., 2107), produce societal benefits, advance industry renewal and technological development, and thus also tackle 'grand challenges' (European Commisison, 2107; OECD, 2017; Mazzucato, 2013). Furthermore, the interconnectedness between measured additionalities and broader outcomes (externalities) is not yet fully known (Ylhäinen et al., 2016). As such, there is also need uncover the impacts that are beyond input and output additionalities currently used in the measurements: These can include long-term analysis, capturing indirect effects and evaluating how the broader challenges and goals of innovation policies are solved.

First, these can include better modeling and estimating long-term effects or taking into account "temporal variance" that can increase our understanding of long-term effects and thus offer more evidence for rationales of innovation promotion. This is because many positive externalities from innovation promotion can take years or decades to fully realize. For instance, long-term evaluations are needed to notice the economic or societal benefits that radical innovations or nascent technology regimes bring. It may be that some positive results influenced by public policies realize after certain other technological or economic developments. Currently, macro-level comparative analysis (e.g. indicators such as innovation scoreboards and benchmarks) do not provide enough impact evidence on assessing long-term macro-level impacts from public innovation policies (Torregrosa-Hetland et al., 2019; Janger et al., 2017). Thus, temporally long term spanning or cross-country macro-studies are still in scarce (See exceptions e.g. van Elk et al., 2019; Torregrosa-Hetland et al., 2019). For instance, the study by Torregrosa-Hetland et al. (2019) show with the longitudinal study how important innovation promotion has been particularly in Finland in fostering significant innovations.

Secondly, innovation promotion impacts can include indirect effects that are hard to capture by typically used direct effect measurements included into additionalities framework. For instance, failed R&D projects, that do not produce any observable positive results, can still be have important spillover effects, without being noticed by the measured additionalities. These sort of benefits are e.g. increased technological competences and human capital in the workforce that then can be utilized by other firms to conduct R&D (Laukkanen & Maliranta, 2019). Overall, it is difficult to observe the intangible knowledge spillovers from failed projects and basic research that can still have an important effect eventually on successful innovations and more applied research and development activities. Studies taking more comprehensive and longitudinal approaches can help to tackle these issues, and the empirical results imply positive effects on a larger scale (e.g. Vanino et al., 2019; Torregrosa-Hetland et al., 2019; Guo et al., 2016). Also, the recent evidence from Wirsich et al. (2016) and Becker (2015) on R&D collaboration results and spillovers resonate with these considerations.

Thirdly, the question remains how to evaluate the broader 'missions' that the innovation promotion policies are supposed to solve, and relate this sort of evidence to government rationale to engage in innovation promotion. On one hand, in the case of positive results observed from innovation promotion (e.g. input additionalities), it is not completely clear that these additionalities realize to innovation outputs or wider and lasting benefits. On the other hand, in the case of negative or unclear direct results (e.g. crowding-out or economic welfare analysis), the policies can still foster realization of wider benefits and positive spillovers such as industry renewal, useful technologies, human capital and societal benefits. For instance, Janger et al. (2017) provide recent overview and critical outlook for how in the European context outputs from R&D and innovations are measured and used in policy context. They argue particularly that that innovation outcome measurement should include also structural changes ("reallocating economic activity towards more knowledge-intensive sectors") and structural upgrades ("getting closer to the frontier in sectors countries are already specialized). The results that innovation promotion leads to more radical innovations points to this direction (Mulligan et al., 2019; Beck et al., 2016). This line of reasoning is also present with recent report by Laukkanen & Maliranta (2019) also stress the importance of public R&D support focusing on broad and ambitions technology programs and regimes, that bring radical innovations and more profound impacts on productivity.

Policy mix: Expanding impact evaluations horizontally

For effective innovation promotion, there is need for different type of policy instruments to be conducted systematically and in conjunction with each other to enable innovation-based growth, and wider technological and economic changes (e.g. Kivimaa & Kern, 2015). Horizontal expansion refers to take into account both mix of innovation policies and their effects, as well as other policies that are not innovation policy related, but influence the outcomes that innovation policies are also seeking to address This horizontal expansion can then help to evaluate the impacts of the innovation policies, foster in designing most effective forms of intervention, and consequently offer justification for publicly conducted innovation promotion.

Particularly, the mission-oriented innovation policies can benefit to take closer look to 'policy mix' discussion. When policy targets are broader goals (externalities), their justification also lies in considering policies in conjuncture that help to foster jointly these broader benefits. Hence, in addition to limited temporality and outcome variables in current studies, there exist also horizontal limitations, namely much of the impact research has still been focusing on individual policies or programs (E.g. see literature review in Torregrosa-Hetland et al., 2019). The importance of policy mix is shown for instance by Mulligan et al. (2019) who find evidence that firms receiving both EU and national level subsidies have higher chance of engaging in riskier, radical innovations, and thus having higher rate of social return (See also Beck et al., 2016).

Considering first the innovation policy mix, recent evidence from research indicates that virtually all European countries use mix of similar policy instruments (Veugelers, 2015), and that these policy mixes are important to consider in conjunction (e.g. Mulligan et al., 2019; Guerzoni & Raiteri, 2015; Kivimaa & Kern, 2016). This is because different forms of policy interventions have an effect on firms over the course of time, and to have as non-biased estimates for the effects of individual policies, it is important to control for all the important confounding factors on estimated relationship between predictors and outcome variables. Particularly, recent studies have shown that subsidy effect estimates are influenced by whether focal subsidy effect is controlled by other received subsidies, i.e. are the effects estimated individually, or as mix of policies from different levels of subsidies (Mulligan et al., 2019). Furthermore, the results from a study by Guerzoni & Raiteri (2015) resonate with these considerations. They analyze public procurement with other policies, such as tax credits, and find that "technology policies" have highest impact when different policies are interacting. Similar type of reasoning is found from an article by Kivimaa & Kern (2016) who focus on mix of energy transition technology policies, and underline the need of wide range of policy instruments in establishing the desired broader transition targets.

Secondly, studies focusing on individual innovation policy programs or instruments do not account for other policies that are not innovation promotion related. As it is unlikely that policy interventions seize completely exist ("laissez-faire state"), opportunity cost evaluations could also include considerations of counterfactuals between different government interventions, such as innovation subsidies and other type of private sector subsidies. For instance, Laukkanen & Maliranta, (2019: 85–87) in their report on government subsidies and national competitiveness in the Finnish context conclude that innovation promotion is the best form of subsidy in terms of the aimed long-term societal benefits vis-à-vis to other subsidies and government interventions.

Conclusions

Next, we will conclude by considering future studies and methodological issues, and then summarize our findings. Overall, as a policy instrument to seek economic and societal benefits, innovation promotion seems by far the most efficient and justified public policy approach in terms of impact evaluations (Laukkanen & Maliranta, 2019). The studies reviewed in this report show that the impact of innovation promotion is on average positive to input and output additionalities (European Commission, 2017; Ylhäinen et al., 2016; Becker, 2015). Additionally, recent studies with more comprehensive policy focus (e.g. Vanino et al., 2019; Wirsich et al., 2016; Beck et al., 2016) or macro-economic focus (e.g. Torregrosa-Hetland et al., 2019) indicate evidence of positive impact on broader economic or societal goals.

Future studies and methodological issues

The integration of research literature and the evidence from various studies is a challenging task. As noted already in this report, there are extensive amount of studies focusing on evaluating the impact of innovation promotion utilizing different research designs and methods to study different policy instruments and programs affecting a wide range of outcome variables from research R&D input additionalities to macro-economic economic and innovation measures. Consequently, there exist also mixed results and heterogeneity that can be attributed both to sampling, policy instrument and contextual particularities (e.g. Edler & Fagerberg, 2017) as well as models and methods used (e.g. van Elk et al., 2019).

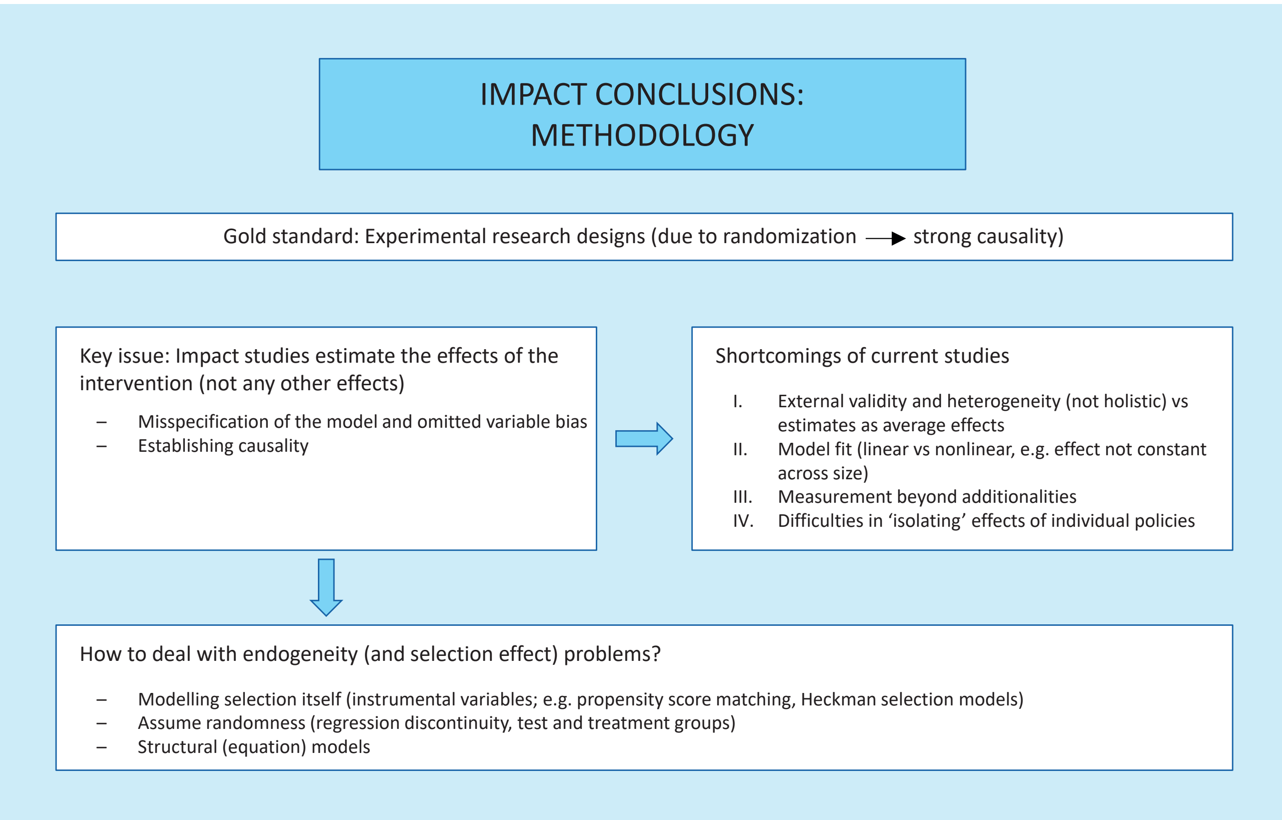
What do the unclear and mixed results tell us? On one hand, these are related to the different methodological and research design issues as well as external validity, i.e. one national context or policy program might be different than others, and these boundary conditions hinder or reduce generalizability. On the other hand, these can also indicate that there exist real heterogeneity in terms of effectiveness of policy instruments in different industry, technology and country contexts. If this heterogeneity is real, then policy practice should consider when innovation promotion is most effective and when not. For instance, this makes Becker (2015: 935–936) conclude that government funding schemas seem to be effective, but these should be targeted more precisely e.g. on smaller firms instead of large firms, and different policy instruments should be coordinated to maximize the positive impacts.

Based on the research literature review, we have compiled following notes about future studies and methodological issues (See also Ylhäinen et al., 2016: 34–37) that are particularly important to consider when assessing impact of innovation promotion with regards to the rationale of government intervention (Figure 1).

- **Measurement: Evaluation framework beyond additionalities:** As far as the goal of innovation promotion is to have broader economic and societal impact, future evaluations should include measures that extend beyond certain input and output variables. It is also important to link the findings from more easily observable additionalities to indirect broader goals ('interconnectedness of the measured outcomes': Ylhäinen et al., 2016) and second-order additionalities (Clarysse et al., 2009; Autio et al., 2008).

- **Model fit and specification of models:** The models used in evaluation should fit to the data, and include the important variables to have as correct estimates as possible. This can include having non-linear model e.g. if the effect is not constant across firm sizes, and making sure that the study includes all important control variables (omitted variable bias) e.g. controlling for other policy instruments to have unbiased estimates (Mulligan et al., 2019). For instance, van Elk et al. (2019) found that different models produced variations in estimates (and in their significance), and concluded that public R&D returns could be attributed to different models rather than samples or assumptions. Mulligan et al. (2019) also showed

Figure 1 Methodological issues for estimating the impact of innovation policy



that estimates varied whether they were controlled by other instruments or not.

- **Difficulties in estimating real effects of single policy instruments:** Related to the omitted variable bias, policy instruments interact and this policy mix can render it difficult for researchers to estimate real effect of individual policies and programs either in the firm-level or at the industry, economy or societal levels. In addition, single policy instruments are embedded to the wider innovation systems and national economy, and thus the developments beyond innovation policies in the wider context can influence the evaluation of effects of policy instruments (Edler & Fagerberg, 2017). Lastly, some of the effects can realize and be observable only in the long-term. This calls for adding right control variables, but also extended research designs "holistically" beyond single policy instruments and adding longitudinal studies to account for long-term development.

- **Dealing with selection effects and endogeneity 'problem'**: An essential issue with impact studies is to estimate the effect of policies (intervention) and not any other effect. This is particularly important in making causal claims. On general level, a gold standard for policy impact research is a type of 'experimental' research designs (e.g. Ylhäinen et al., 2016), because this type of research enables to make stronger causal claims due to the randomization. However, with observational data we don't know if the observed differences (e.g. between two groups of firms) are due to the "intervention" (treatment effect) or due to some other characteristics (e.g. firms that get support are better and would have had higher innovation performance regardless of the treatment). Thus, quasi-experimental research techniques that imitate experimental designs are utilized in order to tackle selection effects and reduce endogeneity problem (See e.g. Ketokivi & McInthos, 2017: Guide & Ketokivi, 2015). Recent research methodology seems to move to a direction in which techniques are used to deal with selection effect and reduce endogeneity 'problem' (Ketokivi & McInthos, 2017). Thus, it is important to continue to improve gradually the impact research methods, e.g. impact evaluation should continue to seek to model selection (Instrumental variables; e.g. propensity score matching, Heckman selection models) or assume randomness (regression discontinuity, test and treatment groups). In addition, structural (equation) models can be used to improve causal inference (e.g. Ylhäinen et al., 2016).

Policy rationales

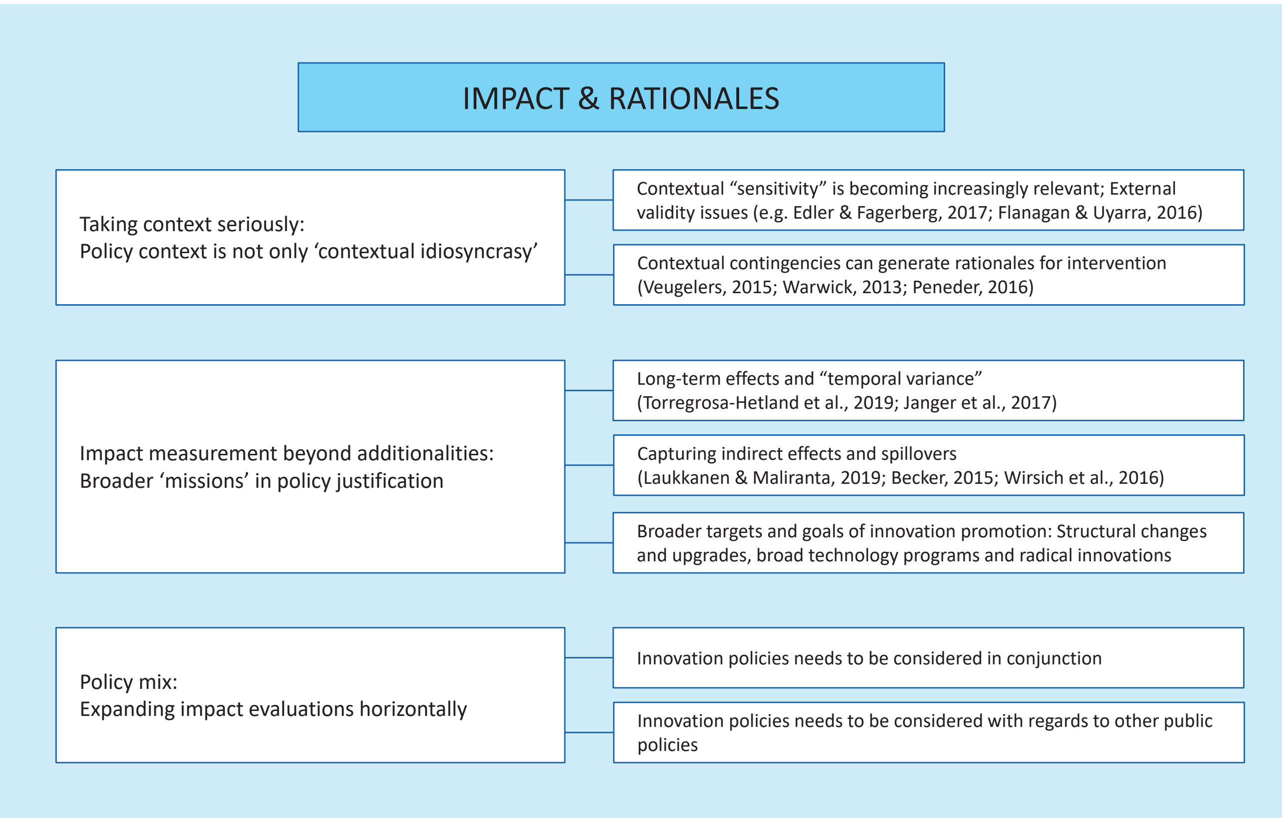
To conclude, policy impact evaluation should adopt what is termed holistic focus both in analyzing policy effects and in designing innovation promotion policies (e.g. European Commission, 2017; OECD, 2017; Edler & Fagerberg, 2017). Based on the studies reviewed and considerations above, this includes taking national contextual specialties and particularities seriously, broadening the measurement variables and frameworks, and understanding the importance of mix of policies in bringing the desired outcomes (Figure 2). The ultimate justification of policies, that are conducted due to the rationales highlighted in the first part of this report, lies in their real effects on firms, economy and society. When the desired goals of the policies are the wider externalities that bring societal benefits, the scope of evaluations should extend accordingly.

To summarize, the implications from impact studies are twofold. First, by just looking single instruments or additionality framework evaluations, it seems that the direct effects – particularly input additionalities – are more positive than negative from public intervention. Also, the problem that public funding suppresses private investments seems at least overestimated (Marino et al., 2016; Choi & Lee, 2017; Becker, 2015). However, even though on a general level the average effects point to positive directions, this does not mean that some instruments or programs are not producing crowding-out effects, or undesirable or insignificant results. Also, behind the average estimates there can be important heterogeneity that policy makers should consider (Hünermund & Czarnitzki, 2019; Mulligan et al., 2019). For instance, it seems that innovation promotion is most effective on young and small firms (Laukkanen & Maliranta, 2019; Becker, 2015), and that some policy programs do not produce desired innovation outputs (e.g. Aiello et al., 2019). Secondly, when widening the scope of investigations temporally and holistically, results point to positive directions e.g. in terms of firm-level average growth (Vanino et al., 2019), enabling radical or novel technologies (Wirsich et al., 2016; Beck et al., 2016) or producing significant innovations in the long run (Torregrosa-Hetland et al., 2019).

Thus, from purely impact evaluation perspective, the justification of state intervention relies on scope and perspective. This also stresses the need of holistic focus that does not attenuate negative impacts or underscore positive ones from single study context or policy instruments. Rather, these should be integrated to more holistic policy evaluation framework that includes both additionalities together with wider economic and societal measurements. Furthermore, as technologies and markets are in constant flux, this sets two challenges for policy makers: 1) constantly evaluate the impact of the policies in relation to the intended goals of intervention that are not static (impact evaluation), and 2) contrast the evaluation results to the broader rationale of innovation promotion in a particular economic and societal context (rationales and justification). Both of these imply constant need to evaluate policy impact and the underlying rationales. For instance, recent change dynamics brought by digital platforms and global business ecosystems underscore the need for the aforementioned evaluations.

Lastly, what do then these tell us about the justification of innovation promotion and the proper role of public policies in this area? It seems that at least safe to conclude that limited interventions are justified based purely on the added value from additionalities. However, when the policy focus extends beyond simple inputs and outputs in bringing industry renewals, increasing productivity, enhancing collaborations and facilitating ecosystems, building long-term competitiveness, and introducing novel and societally useful technologies, this implies also more active and 'mission' oriented role for innovation policy makers. It seems that the research literature tentatively lends justification in terms of positive benefits and impacts to this latter type of 'mission-oriented' innovation promotion policies as well. Furthermore, a more debatable point of view would even underscore the need of such policies in fostering wider societal and economic development through facilitation and introduction of nascent technology fields and radical innovations.

Figure 2 Future directions for innovation policy impact evaluation



Endnotes

[1] These two are not mutually exclusive in terms of policy instruments, because both views stress the need to use e.g. direct R&D support. The key dividing issue here is the scope of interventions, and the impacts the different roles foster.

[2] For instance, Edler & Fagerberg (2017: 12) list 17 different innovation policy instruments.

[3] See Ylhäinen et al. (2016: 42–44) for extensive list of literature concerning the Finnish context.

[4] Related close to this topic, see also Valtiovarainministeriö (2019) & Maliranta et al. (2016).

[5] For reviews, see Ylhäinen et al. (2016); Dimos & Pugh (2016); Becker (2015); Zuniga-Vicente et al. (2014).

[6] More detailed econometric measurement discussion of the returns from R&D, see e.g. Hall et al. (2010).

[7] The typology might be problematic in a sense that non-significant (statistically) is not the same as no association or unclear effect (Altman & Krzywinski, 2017; Wasserstein & Lazar, 2016).

[8] There are also few studies that extend beyond private investment counterfactuals and try to estimate economic welfare effects (Takalo et al., 2013; Takalo et al., 2017).

[9] For more about how to improve outcome measurement in policy formulation and evaluation context, see e.g. Janger et al. (2017) for European policy framework discussion.

[10] Radicic et al. (2018) provide literature overview of how public support influences cooperative behavior. Earlier studies include e.g. Antonioli et al. (2012) and Gök & Edler (2012).

[11] It should be noted that this was very recent study at the time of the synthesis work and we did not yet have full access to the study results. We were able to view the main results, but we were not able to conduct full review on the quality of the study.

[12] Trade journal data: Experts have written about the innovations and this signifies their importance.

[13] They use this term as broad category for all not privately funded R&D, and acknowledge that this measure is highly oversimplifying (van Elk et al., 2019: 55–56).

Bibliography

Aiello, F., Albanese, G., & Piselli, P. (2019). Good value for public money? The case of R&D policy. Journal of Policy Modeling.

Ali-Yrkkö, J. & Pajarinen, M. (2019). Tutkimus- ja kehitystoiminnan kansainvälistyminen. Etla Raportti No 88.

Ali-Yrkkö, J., Kotiranta, A. & Ylhäinen, I. (2017). Katsaus yritysten kasvuun ja sitä koskeviin politiikkatoimiin. Etla Raportti No 79.

Antonelli, C. (2019). Knowledge exhaustibility public support to business R&D and the additionality constraint. The Journal of Technology Transfer, 1–15.

Antonioli, D. & Marzucchi, A. (2012). Evaluating the additionality of innovation policy. A review focused on the behavioural dimension. World Review of Science, Technology and Sustainable Development, 9(2), 124–148.

Altman, N. & Krzywinski, M. (2017). Points of significance: interpreting P values. Nature.

Arrow, K.J. (1951). An extension of the basic theorems of classical welfare economics. Stanford University, Stanford, United States. Cowles Commission Paper, New Series, No. 54.

Arrow, K.J. (1972). Economic welfare and the allocation of resources for invention. In Readings in industrial economics, 219–236. Palgrave, London.

Autio, E. & Rannikko, H. (2016). Retaining winners Can policy boost high-growth entrepreneurship?. Research policy, 45(1), 42–55.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation The importance of context. Research Policy, 43(7), 1097–1108.

Autio, E., Kanninen, S., & Gustafsson, R. (2008). First- and Second-Order Additionality and Learning Outcomes in Collaborative R&D Programs. Research Policy, 37(1), 59–76.

Beck, M., Lopes-Bento, C., & Schenker-Wicki, A. (2016). Radical or incremental Where does R&D policy hit?. Research Policy, 45(4), 869–883.

Becker, B. (2015). Public R&D policies and private R&D investment A survey of the empirical evidence. Journal of Economic Surveys, 29(5), 917–942.

Bérubé, C. & Mohnen, P. (2009). Are firms that receive R&D subsidies more innovative?. Canadian Journal of Economics/Revue canadienne d'économique, 42(1), 206–225.

Borrás, S. & Laatsit, M. (2019). Towards system oriented innovation policy evaluation? Evidence from EU28 member states. Research Policy, 48(1), 312–321.

Branstetter, L.G. & Sakakibara, M. (2002). When do research consortia work well and why? Evidence from Japanese panel data. American Economic Review, 92(1), 143–159.

Bronzini, R. & Iachini, E. (2014). Are incentives for R&D effective? Evidence from a regression discontinuity approach. American Economic Journal Economic Policy, 6(4), 100–134.

Bronzini, R. & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. Research Policy, 45(2), 442–457.

Choi, J. & Lee, J. (2017). Repairing the R&D market failure Public R&D subsidy and the composition of private R&D. Research Policy, 46(8), 1465–1478.

Clarysse, B., Wright, M., & Mustar, P. (2009). Behavioural additionality of R&D subsidies A learning perspective. Research Policy, 38(10), 1517–1533.

Cunningham, P., Edler, J., Flanagan, K. & Laredo P. (2016), 'The Innovation Policy Mix', in J. Edler P. Cunningham A. Gök P. Shapira (eds), Handbook of Innovation Policy Impact , Cheltenham, Edward Elgar, 505–542.

Czarnitzki, D. & Lopes-Bento, C. (2013). Value for money? New microeconometric evidence on public R&D grants in Flanders. Research Policy, 42(1), 76–89.

Czarnitzki, D., Hanel, P., & Rosa, J.M. (2011). Evaluating the impact of R&D tax credits on innovation A microeconometric study on Canadian firms. Research Policy, 40(2), 217–229.

Czarnitzki, D., Kraft, K., & Thorwarth, S. (2009). The knowledge production of 'R'and 'D'. Economics Letters, 105(1), 141–143.

David, P.A., Hall, B.H., & Toole, A.A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. Research policy, 29(4-5), 497–529.

Dechezleprêtre, A., Einiö, E., Martin, R., Nguyen, K. T., & Van Reenen, J. (2016). Do tax incentives for research increase firm innovation? An RD design for R&D (No. w22405). National Bureau of Economic Research.

Dimos, C. & Pugh, G. (2016). The effectiveness of R&D subsidies A meta-regression analysis of the evaluation literature. Research Policy, 45(4), 797–815.

Edler, J. & Fagerberg, J. (2017). Innovation policy what, why, and how. Oxford Review of Economic Policy, 33(1), 2–23.

Einiö, E. (2014). R&D subsidies and company performance: Evidence from geographic variation in government funding based on the ERDF population-density rule. Review of Economics and Statistics, 96(4), 710–728.

European Commission (2017). The economic rationale for public research & innovation funding and its impact. Brussels European Commission. Directorate-General for Research and Innovation.

Fagerberg, J. (2017). Innovation policy Rationales, lessons and challenges. Journal of Economic Surveys, 31(2), 497–512.

Flanagan, K. & Uyarra, E. (2016). Four dangers in innovation policy studies – and how to avoid them. Industry and Innovation, 23(2), 177–188.

Freel, M., Liu, R., & Rammer, C. (2019). The export additionality of innovation policy. Industrial and Corporate Change.

Georghiou, L., Edler, J., Uyarra, E., & Yeow, J. (2014). Policy instruments for public procurement of innovation-Choice, design and assessment. Technological Forecasting and Social Change, 86, 1–12.

Guerzoni, M., & Raiteri, E. (2015). Demand-side vs. supply-side technology policies – Hidden treatment and new empirical evidence on the policy mix. Research Policy, 44(3), 726–747.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. Bell Journal of economics, 10(1), 92–116. Chicago.

Guo, D., Guo, Y., & Jiang, K. (2016). Government-subsidized R&D and firm innovation Evidence from China. Research policy, 45(6), 1129–1144.

Guide Jr, V. D. R., & Ketokivi, M. (2015). Notes from the Editors: Redefining some methodological criteria for the journal. Journal of Operations Management, 37(1), v-viii.

Gök, A. & Edler, J. (2012). The use of behavioural additionality evaluation in innovation policy making. Research Evaluation, 21(4), 306–318.

Hall, B. H., Mairesse, J., & Mohnen, P. (2010). Measuring the Returns to R&D. In Handbook of the Economics of Innovation, Vol. 2, 1033–1082. North-Holland.

Hud, M. & Hussinger, K. (2015). The impact of R&D subsidies during the crisis. [Article]. Research Policy, 44(10), 1844–1855.

Hünermund, P. & Czarnitzki, D. (2019). Estimating the causal effect of R&D subsidies in a pan-European program. Research Policy, 48(1), 115–124.

Laukkanen, M. & Maliranta, M. (2019). Yritystuet ja kilpailukyky. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 2019:33. Valtioneuvoston kanslia, Helsinki 2019.

Hyvärinen, J., & Rautiainen, A.M. (2007). Measuring additionality and systemic impacts of public research and development funding – the case of TEKES, Finland. Research evaluation, 16(3), 205–215.

Janger, J., Schubert, T., Andries, P., Rammer, C., & Hoskens, M. (2017). The EU 2020 innovation indicator A step forward in measuring innovation outputs and outcomes?. Research Policy, 46(1), 30–42.

Ketokivi, M., & McIntosh, C.N. (2017). Addressing the endogeneity dilemma in operations management research: Theoretical, empirical, and pragmatic considerations. Journal of Operations Management, 52, 1–14.

Klette, T.J., Møen, J., & Griliches, Z. (2000). Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. Research policy, 29(4–5), 471–495.

Knockaert, M., Deschryvere, M., & Lecluyse, L. (2019). The relationship between organizational interdependence and additionality obtained from innovation ecosystem participation. Science and Public Policy.

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Research Policy, 45(1), 205–217.

Larédo, P., Köhler, C., & Rammer, C. (2016). The impact of fiscal incentives for R&D. Handbook of Innovation Policy Impact, Cheltenham, Edward Elgar, 18–53.

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R., & Griliches, Z. (1987). Appropriating the returns from industrial research and development. Brookings papers on economic activity, 1987(3), 783–831.

Maliranta, M., Määttänen, N. & Pajarinen, M. (2016). Firm Subsidies, Wages and Labor Mobility. Etla Reports No 60.

Marino, M., Lhuillery, S., Parrotta, P., & Sala, D. (2016). Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. Research Policy, 45(9), 1715–1730.

Mazzucato, M. (2016). From market fixing to market-creating a new framework for innovation policy. Industry and Innovation, 23(2), 140–156.

Mazzucato, M. (2013). The Entrepreneurial State: Debunking Public vs. Private Sector Myths. Anthem Press, London.

Moretti, E., & Wilson, D.J. (2014). State incentives for innovation, star scientists and jobs Evidence from biotech. Journal of Urban Economics, 79, 20–38.

Mulligan, K., Lenihan, H., & Doran, J. (2019). More subsidies, more innovation? Evaluating whether a mix of subsidies from regional, national and EU sources crowds out firm-level innovation. Regional Studies, Regional Science, 6 (1), 130–138.

OECD (2017). OECD Reviews of Innovation Policy: Finland 2017, OECD Publishing, Paris.

Rao, N. (2016). Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade. Journal of Public Economics, 140, 1–12.

Radicic, D., Pugh, G., & Douglas, D. (2018). Promoting cooperation in innovation ecosystems: evidence from European traditional manufacturing SMEs. Small Business Economics, 1–27.

Solow, R.M. (1957). Technical change and the aggregate production function. The review of Economics and Statistics, 312–320.

Takalo, T., Tanayama, T., & Toivanen, O. (2013). Estimating the benefits of targeted R&D subsidies. Review of Economics and Statistics, 95(1), 255–272.

Takalo, T., Tanayama, T., & Toivanen, O. (2017). Welfare effects of R&D support policies. Bank of Finland Research Discussion Paper, (30).

Torregrosa-Hetland, S., Pelkonen, A., Oksanen, J., & Kander, A. (2019). The prevalence of publicly stimulated innovations. A comparison of Finland and Sweden, 1970–2013. Research Policy.

Valtiovarainministeriö (2019). Tuottavuuden tila Suomessa. Miksi sen kasvu pysähtyi, käynnistyykö se uudelleen. Valtionvarainministeriön julkaisuja. 2019:21.

van Elk, R., ter Weel, B., van der Wiel, K., & Wouterse, B. (2019). Estimating the Returns to Public R&D Investments Evidence from Production Function Models. De Economist, 1–43.

Vanino, E., Roper, S., & Becker, B. (2019). Knowledge to money: Assessing the business performance effects of publicly-funded R&D grants. Research Policy.

Veugelers, R. (2015). Mixing and matching research and innovation policies in EU countries (No. 2015/16). Bruegel Working Paper.

Wasserstein, R.L., & Lazar, N.A. (2016). The ASA's statement on p-values: context, process, and purpose. The American Statistician, 70(2), 129–133.

Wanzenböck, I., Scherngell, T., & Fischer, M.M. (2013). How do firm characteristics affect behavioural additionalities of public R&D subsidies? Evidence for the Austrian transport sector. Technovation, 33(2–3), 66–77.

Wirsich, A., Kock, A., Strumann, C., & Schultz, C. (2016). Effects of university–industry collaboration on technological newness of firms. Journal of Product Innovation Management, 33(6), 708–725.

Williamson, S.D. (2002). Macroeconomics. 2nd edition. Pearson.

Ylhäinen, I., Rouvinen, P., & Kuusi, T. (2016). Katsaus yksityisen t&k-toiminnan ja sen julkisen rahoituksen vaikuttavuuteen. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 57/2016. Valtioneuvoston kanslia.

Zúñiga-Vicente, J.Á., Alonso-Borrego, C., Forcadell, F.J., & Galán, J.I. (2014). Assessing the effect of public subsidies on firm R&D investment a survey. Journal of Economic Surveys, 28(1), 36–67.

ETLA

Elinkeinoelämän tutkimuslaitos

ETLA Economic Research

ISSN-L 2323-2447,
ISSN 2323-2447,
ISSN 2323-2455 (Pdf)

Publisher: Taloustieto Oy

Tel. +358 (09) 609 900
www.etla.fi
firstname.lastname@etla.fi

Arkadiankatu 23 B
FIN-00100 Helsinki