

Economics of Finnish Innovation Policy*

Tuomas Takalo

Bank of Finland and VATT Institute for Economic Research

Otto Toivanen

Aalto University, KU Leuven, CEPR, HECER

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Abstract

We provide both a qualitative analysis of the various Finnish innovation policies and a quantitative welfare analysis of the Finnish R&D subsidy policy and tax credit regime of 2013-2014. In the qualitative analysis we argue that innovation policy should be based on a bottom-up approach rather than a mission oriented, top-down approach. We highlight areas of the Finnish innovation policies that should be evaluated rigorously. Our counterfactual welfare analysis suggests that the Finnish R&D subsidy and tax credit policies increase R&D investments and social externalities markedly, but once the costs of the policies are taken into account, they hardly increase welfare.

* Tuomas Takalo, Bank of Finland and VATT, E-mail: tuomas.takalo@bof.fi. Otto Toivanen, Aalto University, KU Leuven, CEPR and HECER, E-mail: otto.toivanen@aalto.fi. We thank Allan Seuri for excellent research assistance and many useful comments. We also thank seminar participants at the Economic Policy Council Finland, ETLA, and Herkko Hietanen, Ari Hyytinen, Martti Kivistö, Jussi Laitila, Pierre Mohnen, Ulla-Maija Mylly, Juha Pulliainen, Petri Rouvinen, Samuli Simojoki, Pekka Sääskilahti, Tommi Uhari, Rainer Oesch ja Ilari Valjus for comments and discussions.

1 Introduction

Enhanced productivity through innovation is the main driver of economic growth (see, e.g., Aghion and Howitt, 2009) and also the hoped-for savior for countries whose growth has stagnated since the 2008 economic crisis. Economic theory, with Nelson (1959) and Arrow (1962) being the seminal contributions, suggests that market failures may provide a strong motivation for government intervention to promote innovative activities. These observations have not gone unheeded: governments around the world have implemented various direct and indirect innovation policies to increase productivity through innovation. We review what economic research has to say about the role of the government in fostering innovation and about optimal innovation policy in a small open economy like Finland. We then evaluate both qualitatively and quantitatively how well Finnish innovation policy squares with the policies suggested by economic research.

The starting point of our analysis is the fundamental challenge of innovation policy: how to encourage the development of new innovations while at the same time achieving maximal diffusion of those innovations? This conflict stems from the universal good nature of knowledge,¹ and presents a two-edged sword for a small open economy like Finland. On the one hand, the fundamental challenge means that Finland should actively suck in new knowledge generated by the more than 99% of human population living elsewhere. On the other hand, the challenge means that a large part of the very basis for an active government role in supporting innovation, the wedge between social and private returns, disappears. Consumer surplus, for example, represents often a large part of the wedge between social and private welfare. In the case of, say, the ele-

¹ Admittedly there is evidence that knowledge spillovers are still to some extent local and this provides a rationale for favoring agglomeration within countries. At the same time, there is evidence of increasingly strong international knowledge flows (see, e.g., Griffith, Lee, and Van Reenen 2011). As an early example, the first Finnish telephone company was established in Helsinki in 1877, only a year after Bell got his patent on the telephone in the US.

vator producer Kone, most of the consumer surplus generated by new elevator innovations resides somewhere else but in Finland, and should be ignored when designing an innovation policy that maximizes the social welfare in Finland. Also, technological spillovers contributing to the welfare wedge partially flow abroad. Almost without exception, the existing literature on innovation policy takes a “large country” approach. As we will discuss, some policy conclusions change markedly when a small open economy approach is adopted.

Finnish innovation policy relies currently on intellectual property, subsidies and public production while other innovation policy tools such as tax reliefs and prizes are in limited use. We discuss the way these different policy tools are used in Finland and what the economic literature says about their pros and cons.

Besides assessment of various direct *innovation policies*, this report contains also a brief discussion of some *policies for innovation* such as basic research, education, competition policy, and financial and labor market regulations. As pointed out by the OECD (2010, 2015) and Takalo and Toivanen (2016), such policies that indirectly affect innovation may be more important than the direct innovation policies, especially in small open economies where benefits from direct support of private R&D and strong domestic intellectual property rights can be low.

The main focus of this report is however in a quantitative counterfactual analysis of the Finnish R&D subsidy policy, and the R&D tax credit policy used in Finland in 2013-2014.² For brevity, we call these policies “the Finnish R&D subsidy policy” and “the Finnish tax credit policy of 2013-2014” but the reader should keep in mind that our welfare evaluations are based on counterfactuals. Empirical welfare evaluations of actual R&D policies are seldom carried out because of the difficulties in measuring aggre-

² We will mostly use the words “R&D”, “invention”, and “innovation” interchangeably albeit they do involve subtle but important differences. See, e.g., Carlino and Kerr (2015) for a discussion.

gate welfare. To overcome this measurement problem, our evaluation is based on an ex ante perspective: given the existing data we attempt to measure the expected welfare benefits of a policy if it had been implemented as planned. While similar counterfactual welfare evaluations are commonplace in some other areas of economics research (see, e.g., Caliendo et al. 2017 for EU enlargement, and Dhingra et al. 2017 for the trade effects of Brexit), they are seldom used in evaluation of innovation policy (exceptions include Takalo, Tanayama, and Toivanen, henceforth TTT, 2013 and 2017, and Takalo and Toivanen 2017). Usually, innovation policy evaluations focus on capturing the causal effect of a given innovation policy instrument, and assume that the level of innovation is a sufficient proxy for welfare. As suggested by our report, however, innovation and welfare in a small open economy are not necessarily equivalent. For example, our results suggest that the optimal R&D policy should aim at doubling the level of R&D in Finland; yet welfare gains from such a policy would be small.

The remainder of this report is organized as follows. In the next section we review the economic literature on innovation policy from the perspective of a small open economy like Finland. The section begins with a discussion of the role of government in promoting innovation. In Section 3 we document the evolution of the major innovation policies used in Finland and provide a qualitative evaluation of them. In Section 4 we provide a quantitative evaluation of the Finnish R&D subsidy policy, and the R&D tax credit regime of 2013-2014. Section 6 concludes.

2 Economics of Innovation Policy

2.1 The Role of Government in Fostering Innovation

There is a consensus across various disciplines that a laissez-faire market economy would provide too little innovation, which creates a *prima facie* case for a government intervention. This broad consensus on the need of the policy and its goal - to foster innovation - has not lead to agreement as to the role of the government or specific means

to achieve the goal. For example, two recent books written by academics for the wider audience illustrate the large variation in policy advice: Marianne Mazzucato in her 2013 book *The Entrepreneurial State: Debunking Private vs. Public Sector Myths* makes strongly the case that governments should take an active role in choosing the direction of research, development and innovation activities. In contrast, Josh Lerner in his 2009 book *Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed- and What to Do about It* argues that such a top-down approach is likely to fail much more often than to succeed, and governments should focus on creating the right institutional environment for the private sector innovation to flourish.³

At the heart of the economic approach to innovation policy is the concept of market failure: market failure creates a wedge between social and private returns to innovative activity. The main market failure in the area of innovation is the imperfect appropriability of the returns to R&D investments, as innovative firms and individuals cannot capture all benefits that their innovations provide, but share them with consumers, other stakeholders and workers within the firm and other firms and users (Nelson 1959 and Arrow 1962). For example, using Finnish data, Aghion et al. (2017a) show that inventors capture less than 10% of the overall wage increase within the inventing firm due to invention. Financial market imperfections in relation to the funding of R&D investments are often mentioned as another important market failure (see Hall and Lerner 2010 and Kerr and Nanda 2015 for surveys).

³ There are other popular books with similar tones, e.g. Atkinson (2015) argues for a strong role for the government in shaping technological change so as to encourage employment and reduce inequality whereas Acemoglu and Robinson (2012) emphasize the right institutional structure to create incentives for innovative efforts. Takalo (2014) and Alaja (2017) describe the merits of bottom-up approach and Mazzucato's views in Finnish, respectively.

As a result of these market failures, the private sector is likely to invest too little in R&D activities.⁴ Roughly speaking, the standard economics literature suggests that the private sector should take care of activities where social welfare mainly consists of private profits, and the government should provide those activities with high social returns but low or non-existing private profits. In the possibly large grey area in-between, the government may design policies that complement innovation in the private sector and steer the private sector to choose actions that are closer to the social optimum.

The market failure approach has been heavily criticized by some scholars such as Nelson (2009) and Mazzucato (2013) who argue that it allows too narrow a role for the government. In our view the critique is on one hand partially misplaced, but on the other hand raises a fundamental question of what government can be expected to do.

We think that the critique of the market failure approach is partially about semantics: in most cases that Mazzucato (2013) brings forth to argue for an active government, the government can be viewed as correcting market failures. Her examples cover cases that an economist would characterize in terms of missing markets, imperfect competition, imperfect information and other systemic problems not solved by market forces. These are all examples of market failure at work. As an example, in the case of a missing market, the government can attempt to create the market, e.g., by investing in innovation itself, via public procurement, or by providing the right institutional structure for market forces to operate.

Furthermore, the standard economics literature often emphasizes that the main market failure occurs at the extensive rather than at the intensive margin. If a market failure occurs at the intensive margin, it means that private sector entities invest, but too

⁴ R&D projects may also generate negative social externalities (e.g., business stealing and duplication of R&D costs, and harmful environmental effects). While in theory these adverse effects of R&D investments could result in overinvestment in R&D, evidence suggests that underinvestment due to imperfect appropriability and financial market imperfections is a much more likely outcome (see Jones and Williams 1998, Bloom, Schankerman, and Van Reenen. 2013, and TTT 2017).

little from the society's point view. If a market failure occurs at the extensive margin, it means that the private sector does not invest at all even though from the society's point of view it should. Many mainstream scholars and commentators have emphasized that innovation policy should only focus on the extensive margin, i.e., the government should implement or subsidize projects only if they would not otherwise be implemented (see, e.g., Einiö 2013 and Pursiainen 2017). For example, it is widely accepted that governments should support or directly invest in basic research where social returns are high but private returns are negative so that markets do not exist. Since a missing market by definition means a market failure at the extensive margin, these suggestions resemble the suggestion to focus on the extensive margin.

Setting the semantics aside the critique raises two deeper issues. First, can the main effects of innovation policies be obtained at the intensive or at the extensive margin? Mazzucato's call to "go beyond the market failure motivation" is based on her view that missing markets are an important object that policy makers should address. The standard economic approach to innovation agrees on her view on the basis of market failure, but quantitative research provides no conclusive evidence on whether missing markets are a larger or smaller market failure than the other market failures associated with innovation. On the one hand, it is widely thought that major breakthrough innovations come from start-ups (see, e.g., Akcigit and Kerr, 2016 for evidence supporting this view). On the other hand, the intensive margin, and innovation by large firms may matter more than the extensive margin and start-up innovation (see Bloom, Schankerman, and Van Reenen 2013, Garcia-Macia, Hsieh, and Klenow 2016 and TTT 2017).⁵ One reason for this finding stems from consumer surplus, often ignored in innovation policy discussions. For example, even the largest and most profitable innovative

⁵ Mazzucato (2014), too, argues that a focus of innovation policy on entrepreneurship and start-up finance may be misplaced.

firms such as Apple cannot price discriminate so efficiently that they would capture all consumer benefits created by their innovations. Hence it may make sense, e.g., to subsidize R&D projects by the largest firms, too.

The second, and perhaps the most substantial, part of the critique concerns the role the government in innovation policy. Mazzucato (2013) argues for a mission-oriented approach where government takes strong initiatives where to invest. In contrast, many mainstream scholars such as Lerner (2009a) argue that such attempts are bound to fail much more often than succeed, and the government should concentrate on providing the right conditions for the private sector to innovate.

Economic theory often features a benevolent and omnipotent government which can implement marvellous things, innovation policy included (see, e.g., TTT 2017 for an innovation policy analysis that incorporates such a social planner). The question is to what extent we can expect the government to act benevolently and to what extent it is omnipotent. In these respects the standard economic approach to innovation policy is much more cautious than Mazzucato (2013), for two main reasons.

First, all government policies are vulnerable to moral hazard, lobbying, and regulatory capture. Government officials are using taxpayers' money and do not necessarily have the correct incentives to invest them in a well-meaning way. Many innovation policies are such that the benefits of the policies are concentrated to certain interest groups, but costs are spread out to consumers and taxpayers, making them particularly vulnerable to lobbying. In Section 3 we provide casual evidence of these problems in the context of the Finnish intellectual property rights policy design. The mission oriented top-down policies are by their nature more exposed to lobbying by interest groups than bottom-up policies, especially if the bottom-up policies are implemented in a rule-based manner that leave less room for discretion.

Second, even if we assume a benevolent government, there is considerable uncertainty as to who will succeed in research and in commercializing that research and when. In designing effective innovation policies, the government should also be able to anticipate the response of economic agents (e.g. firms, inventors, public sector researchers) to its policies. These endemic informational problems in innovation create scope for both positive and negative unintended consequences of well-meaning government policies. Mazzucato's (2013) book contains examples of positive and Lerner's (2009a) book of negative unintended consequences.⁶

One approach, adopted from Holmström and Myerson (1983), to evaluate the government's potential for welfare-improving innovation policies is to assume that an innovation policy maker encounters the same informational obstacles as private sector entities providing funding for innovation, such as business angels, venture capitalists and banks, and ask whether the policy maker can in such circumstances increase welfare and how. One could go still further, as, e.g., Lach, Neeman, and Schankerman (2017) do, and assume that policy makers have worse information than private sector innovation financiers. For an informationally disadvantaged policymaker, a straightforward policy recommendation is to invest in basic research and development of general purpose technologies where informational and appropriability problems on the one hand prevent private sector from investing and on the other hand create a scope for large, positive unintended externalities for the rest of the economy.

Ultimately, whether and how the government's innovation policies can increase welfare are empirical questions. The questions are difficult since answering requires information about the counterfactual; what if the government money would have been spent in some other way or what if some other policy would have been in place instead?

⁶ Lerner (2009a) also cites Sitra and Tesi (Suomen Teollisuussijoitus Oy), the two Finnish innovation and venture capital funds, as examples of how flawed designs compromise policy-makers' good intentions.

A related issue is that all government policies cause distortions: for example, even under zero interest rates for government debt, the shadow cost of government funds is above one.⁷ This means that social returns to innovation policies must be significantly higher than their budgetary costs to make them worthwhile.

Because of the difficulty of constructing the counterfactual, there are not many attempts to estimate welfare effects of innovation policies. Our own estimations (see Section 4) suggest that the scope for welfare-improving innovation policies in small open economies like Finland is perhaps much smaller than what is commonly thought. Our results are, however, too new to be used to radically change the consensus of the innovation policy practice before they are validated by future research.

Otherwise, the evidence on the welfare effects of innovation policies is more indirect. As we will review in the next sections, the empirical literature has been able to create a consensus in some areas, but has so far failed to provide a consensus on the welfare effects of many policies

To summarize, there is consensus in that governments should be active in the area of innovation policy but the mission-oriented, or the top-down approach suggested by, e.g., Mazzucato (2013), stands in a marked contrast with the bottom-up approach suggested by the standard economics research. The top-down approach lacks solid theoretical foundations and the available evidence, surveyed, e.g., by Lerner (2009a), indicates that the top-down policies do not work on average. While there are no empirical studies that would have attempted to directly evaluate the bottom-up approach, it is theoretically justified and there is indirect evidence to support it. In our view, uncertainty related to outcomes of innovative activities and the direction of technological progress (e.g., the

⁷ Kuismanen (2005) estimates the dead-weight loss of the Finnish taxation to be 15%, which is a lower figure than in many other countries. In a more recent paper, Barrios, Pycroft, and Saveyn (2013) cite an estimate of 1.5 for the long-run marginal cost of the Finnish government's funds. We use the value 1.2 for the shadow cost in our evaluation of the Finnish R&D support policies in Section 4. Innovation policies that do not require tapping into distortionary taxation such as intellectual property cause other kind of distortions.

impact of digitalization), benefits of agglomeration, and small-open economy considerations call for a predictable institutional environment that allows research-resources to agglomerate through a bottom-up process and to flow to their best, often unexpected, uses (see Takalo and Toivanen 2016 for further discussion).

2.2 Direct Innovation Policies

In this subsection, we first discuss intellectual property rights, then government funding of private R&D, and conclude by summarizing briefly arguments for and against other direct innovation policies.

2.2.1 Intellectual Property Rights

Intellectual property has many facets that have been extensively analyzed (see, e.g., Menell and Scotchmer 2007, for a survey). Intellectual property attempts to solve the fundamental tradeoff of innovation policy by legal means, as it confers an innovator a temporary exclusive right to her innovation. This right provides a possibility to monetize innovation and thereby enhances the incentives to innovate. After the right expires, the innovation and protected knowledge becomes freely usable. The basic disadvantages of intellectual property right are the reduced consumer surplus and technological spillovers that follow when the property right is in force. Basic economic theory (see, e.g., Chapter 19 in Bellefamme and Peitz 2015 for a summary) suggests that as a result of these tradeoffs, there should be an inverse-U shaped relationship between social welfare and the strength of intellectual property protection.

Somewhat puzzlingly, however, there is little evidence to date that stronger intellectual property generates more innovation (see, e.g., Lerner 2009b, Boldrin and Levine 2013, and Moser 2013). As a necessary (but not a sufficient) condition for a welfare improving intellectual property policy is enhanced incentives to innovate, the finding firmly suggests that weaker intellectual property rights would be optimal.

Over the recent decades economic research of intellectual property has focused on cumulative innovation. This emphasis has produced a more nuanced view of the intellectual property system. On the positive side, the intellectual property system has created a market for knowledge (for evidence, see, Branstetter, Fisman, and Foley 2006, Serrano 2010, Galasso, Schankerman, and Serrano 2013, and Farre-Mensa, Hedge, and Ljungqvist 2016) that has facilitated knowledge transfers and the financing of innovations.

The academic literature has documented a major drawback of the intellectual property system: the boundaries of intellectual property rights are inherently imprecise and are ultimately defined by courts. From an innovator's point of view this leads to a threat of intellectual property disputes which acts as a tax on innovation. As a result, the basic theoretical result of the positive effect of stronger intellectual property on innovation may be overturned when innovation is cumulative and boundaries of intellectual property imprecise (see, e.g., Bessen and Maskin 2009). In line with this theory, Galasso and Schankerman (2015) and Sampat and Williams (2017) find no effects of stronger patent protection on cumulative innovation.⁸ Another mechanism potentially explaining a non-positive effect of stronger intellectual property on innovation is that longer patent duration can encourage imitation, and thus dilute the positive effect of longer duration on innovation (see Izhak, Saxell, and Takalo, 2017, for theory and evidence).

Even when these more complex effects are acknowledged, research suggests that stronger intellectual property rights are hardly welfare improving. If anything, empirical research suggests that social costs related to imprecise boundaries of intellectual property rights are rising and, at least in the US, may exceed the social benefits of the intellec-

⁸ Bessen and Maskin's (2009) result is based on strong assumptions such as R&D costs being fixed (see e.g., Carpentier and Kultti 2005). Less radical assumptions in the context of cumulative and sequential innovation tend to generate an inverse-U relationship between the level of innovation and strength of IP protection (see, e.g., Horowitz and Lai, 1996, Hunt 2004, and Parra, 2017).

tual property system (Jaffe and Lerner 2004, Bessen and Meurer 2008, Boldrin and Levine 2013, and Bessen et al. 2015).⁹

For a small open economy, an optimal intellectual property system would probably warrant strong intellectual property rights in the rest of the world but weak intellectual property rights at home (Scotchmer 2004a). This would allow the country's own citizens and firms to use and experiment with innovations developed elsewhere more easily, but exporting firms would nonetheless have incentives to innovate thanks to strong intellectual property rights abroad.¹⁰ The drawbacks of strong intellectual property rights would be borne by citizens and firms abroad. Note that "weak" does not mean that for example, patent examination quality should be lax; on the contrary, for a small open economy, it should be optimal to have stringent patent examination system with relatively high application and renewal fees; this would keep the number of patents granted in the country's jurisdiction low but their average value high.

2.2.2 Government Funding of Private R&D

Public funding of private R&D through subsidies, soft loans, and tax incentives is a widely used policy tool. OECD countries spent over 40B\$ of taxpayers' money on supporting private R&D in 2015.¹¹ Governments have also adopted more tools over time, especially introducing various tax breaks, e.g. for R&D expenditures, intellectual property revenues, and financing of start-ups. Figure 1 displays the use and level of R&D subsidies and tax credits in OECD countries in 2011, the latest year for which such a figure is available (OECD 2017 contains updated details of the R&D subsidy and tax

⁹ An exception is Aghion, Howitt, and Prantl (2015) who show that countries with stronger intellectual property regimes may benefit more from reforms that enhance competition in the marketplace.

¹⁰ See Holmström, Korkman, and Pohjola (2014) who apply a similar argument to the Finnish case.

¹¹ We arrive at this figure by multiplying Business Enterprise R&D (BERD) measures in 2010 PPP US\$ by the percentage of BERD financed by government, obtained from OECD Main Science and Technology Indicators www-site (last accessed on 28 December, 2017).

credit schemes in the OECD countries). Finland is in the minority in the sense that it only relies on R&D subsidies.

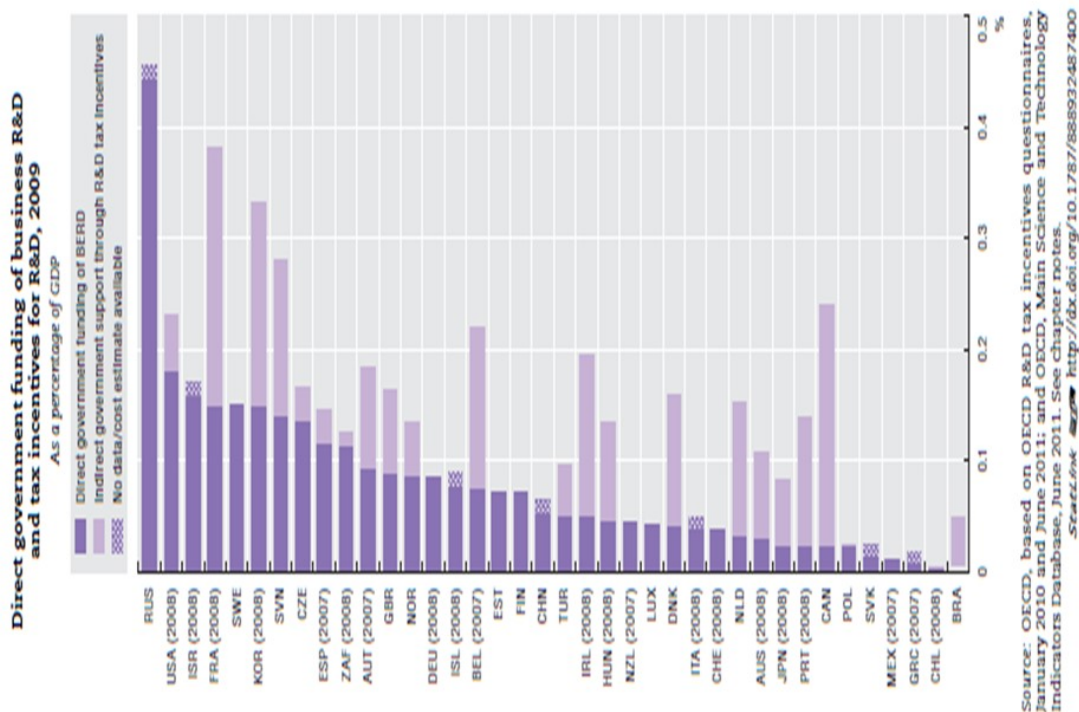


Figure 1. Use of R&D subsidies and tax credits in OECD countries. Source OECD (2011).

The basic mechanism of most of these support schemes is similar: the government pays some fraction of the marginal cost of R&D. Lowering the marginal cost means that a supported firm invests more, at least partially closing the gap between the privately and socially optimal levels of R&D. There is also a hope that additional finance by the government would have an impact at the extensive margin (e.g. by attracting new firms to start R&D), but recent research shows that existing policies merely lowering marginal costs of R&D are not effective policy tools to this end (see Czarnitzki et al. 2015, Lach, Neeman, and Schankerman 2017, and TTT 2017). Extrapolating the results from the literature on corporate taxation (e.g., Devereux and Griffith 1998), it is likely that

average R&D cost, and not the marginal one, is what matters for the firms' discrete decisions on whether to start investing in R&D or not.

These financial support policies have also important differences. First, subsidies can be tailored for each project for which the government receives an application, whereas every eligible firm can in principle make a claim for tax credits.¹² One thus needs to trade off the propensity of firms to apply and receive support with the government's ability to tailor the support to the particular project. The application process for subsidies also means that the government may become a focal point for information on emerging agglomeration patterns.

Second, tax incentives in their purest form only work for firms that are profitable and pay taxes. This severely hampers their effectiveness in encouraging start-up innovation. Many countries like Norway and the Netherlands have therefore resorted to "subsidy-like" tax incentives where the R&D-performing firm gets what amounts to a discount on labor-related social costs and taxes. Furthermore, there is often a cap on the amount of the tax credit the firms can claim. For example, both the Finnish R&D tax credit scheme of 2013-2014, and the Swedish one introduced in 2014 have such a cap. In Section 4 we show how such a cap mainly results in a transfer of government funds to firms investing beyond the cap, with an effect only on the incentives to apply for R&D subsidies. For this reason some countries (e.g., US) give tax credits on incremental R&D. This in turn distorts firms' investment decisions over time.

Given the amounts of tax euros channeled to private sector R&D through these policy tools, it is no surprise that a vast empirical literature studying their treatment ef-

¹² In the Finnish data used by TTT (2017) approximately 20% of firms apply for R&D subsidies. This is in line with the application percentage observed in some other European countries (see Czarnitzki et al. 2015). Note that the uptake of R&D tax credits is not universal either. Only some 800 firms took advantage of the Finnish tax credit scheme of 2013-2014 (see Kuusi et al. 2016). Busom, Corchuelo, and Martínez-Ros (2014) report a usage rate of less than 50% in Spain for R&D – performing (i.e., eligible) firms, and in the Netherlands the usage percentage is round 80% for firms with > 10 employees and round 40% for smaller firms (Verhoeven, van Stel, and Timmermans 2012).

fects exists.¹³ The literature has mostly but not exclusively studied a (causal) effect government financial support on private R&D investments or outcomes (exceptions include Wallsten, 2001, Demeulemeester and Hottenrott 2015, Grilli and Murtinu 2015, Hünermund and Czaritzki 2016, and Howell 2017 who study effects on employment, cost of debt, RJV formation, firm growth, and venture capital backing, respectively). The findings in general indicate an additionality effect, e.g., that a euro of public money given to a firm increases the firm's R&D investments by more than a euro. For example, Einiö (2014) finds that one subsidy euro from Tekes induces a Finnish firm's R&D worth 1.4 euros in the first full support year, and Dechezleprêtre et al. (2016) find that the UK tax credit scheme increases firms' R&D investments by 1.7 pounds for every pound of taxpayer money.

TTT (2013b), however, emphasize that the extent to which government support increases private R&D does not directly map into social benefits. The reason is that a firm equates the private benefits of R&D with the marginal cost of R&D, but ignores consumer surplus and knowledge spillovers. For example, a small increase in an R&D project creating large consumer surplus and spillovers may be socially much more beneficial than a large increase in R&D in a project with small (but still positive) consumer surplus or spillovers.

In small open economies, one should pay attention to the share of consumer surplus and spillovers flowing outside the national borders where they do not benefit the local tax payers (Czarnitzki et al. 2015, Conti 2015, 2017, and Takalo and Toivanen 2016). Existing R&D subsidy and tax credit policies sometimes impose restrictions on offshoring of government funded projects, or on transferring knowledge abroad. On the one hand, such restrictions may hamper the firm's ability to raise external funding

¹³ For literature surveys on the effects of R&D subsidies, see David, Hall, and Toole (2000), Klette, Møen, and Griliches (2000), García-Quevedo (2004), Cerulli (2010), and Zúñica-Vicente et al. (2014), and on the effects of R&D tax incentives, see Hall and van Reenen (2000), Mohnen and Lokshin (2010), and European Commission (2013).

abroad (Conti 2017). On the other hand, the open-economy view could call for more radical changes in policy-thinking. For example, if the outflows of consumer surplus and spillovers constitute a large share of the welfare effects of R&D beyond private profits, private R&D without support may be close to the socially optimal level from a national point of view (see TTT 2017 for evidence). As another example, while standard economic theory suggests that R&D projects waiving (strong) intellectual property should be prioritized when granting R&D subsidies, in a small open economy the argument is weaker in the case of exporting firms. These open-economy considerations also suggest that the benefits from international coordination of R&D support policies could be large (see Czarnitzki et al. 2015).

2.2.3 Other Innovation Policy Tools

Prizes and contests are an old way of supporting innovation (see Scotchmer 2004b) but over the past century they have been relatively little used. Using Maurer and Scotchmer's (2004) classification of prize types, *targeted prizes* are posted ex ante by a sponsor (e.g., a public agency) who has identified a problem to be solved. The prize is awarded to the first entity that solves the problem. For example, the Clay Mathematics Institute announced in 2000 a \$1,000,000 prize for the first solution for each of seven unsolved mathematical problems.

Blue-sky prizes are awarded ex post for innovations that the sponsor considers valuable. A blue-sky prize could be granted in an ad hoc manner each time the sponsor observes a particularly valuable innovation, or the sponsor can commit to grant the prize. The Nobel Prize is the most well-known example of blue-sky prizes, the Finnish Millennium Technology Prize being another. The incentive effects of blue-sky prizes are probably quite small, and they should be seen more as a marketing tool.

In contrast, targeted prizes could constitute an efficient innovation policy tool. If the rewarded solution is put in the public domain for free use, the prizes completely

solve the ex post problem of diffusion of innovations. The problem with targeted prizes is that the sponsor should know ex ante what should be invented.

Setting up contests for targeted prizes helps to aggregate information from innovators, as the sponsor can compare the proposals. Modern information and communication technologies have enabled both the public and the private sector to set up innovation prize platforms (such as Challenge.gov) where not only solutions but also problems are posted. Such crowdsourcing provides a new avenue to identify the right problems for prizes and set up contests.

Another tricky task with prizes is to make sure that they reflect the social value of innovations so that they are of proper size. Estimating the proper size for a prize is difficult since this not only depends on the value of an innovation but also the costs of creating it. Kremer (1998) proposes an interesting public patent-buyout solution to the problem of eliciting information: the patent authority could auction a patent right and use information revealed by bids so as to give an appropriate reward to the patent applicant. To preserve incentives in the auction, a patent grant should de facto be granted with a small probability, otherwise the invention could be put in the public domain. Shavell and Van Ypersle (2001) propose a simpler, but less perfect, mechanism to relate the size of prize to the value of innovation, reminiscent of the royalty-based licensing fees.

Contests inherently involve duplication of R&D costs when the participants race against each other to obtain the prize. Furthermore, being monetary rewards, prizes are vulnerable to misuse and ex post opportunism (e.g., once the problem is solved, why should the sponsor give the reward).¹⁴ These moral hazard concerns may however not be of the first-order importance, since well-functioning governments have been able to solve same the time-inconsistency problem associated with patent policy relatively well.

¹⁴ A classic example of these problems is the Longitude prize (see., e.g, Sobel 1995).

To summarize, targeted prizes might be used more widely in innovation policy.¹⁵ For example, there are numerous diseases that are relatively more prevalent in Finland. Posting a correctly designed prize would be a fairly straightforward way to create incentives to come up with new treatments for such diseases.

Public procurement and production also provide tools for innovation policy. Governments can provide services to complement private sector innovation, work in partnerships with private entities, buy innovations from private contractors, create markets for the private sector, or directly produce innovations themselves. Such public procurement and production of innovations and complementary services have been widely used through economic history (see, e.g., Scotchmer 2004b and Mazzucato 2013), but still may have some untapped potential for innovation policy (Edler and Georghiou 2007). Czarnitzki, Hünermund, and Moshgbar (2018), for example, find that German public procurement fostering innovation leads to an increased turnover-share of new product and services. The current Finnish government (Finnish Government 2015) has set a target that at least 5% of the Finnish public sector's procurement (around 27 billion euro annually) should be used as an innovation policy tool.

In theory, some public innovation support services, direct public production and innovation procurement share the benefits and costs with targeted prizes. On the one hand, the ex ante incentives to innovate can be inefficient, since the decision of what to invent and what information to produce is made by the government. On the other hand, nothing prevents efficient diffusion of innovations ex post. However, a part of public procurement and production is concentrated on nationally strategic sectors such as defense with the purpose of *minimizing* the diffusion of research results.

¹⁵ There appears to be emerging interest in using prizes in the Finnish innovation policy, see, e.g., <https://www.sitra.fi/blogit/lopeta-lottoaminen-ja-osallistu-innovaatiokilpailuun/>.

Promotion of *research joint ventures* (RJVs) and other forms of R&D cooperation is a widely used tool of innovation policy in industrialized countries. RJVs allow participating firms to internalize technological spillovers and thereby they should enhance R&D efforts. Therefore, RJVs are prioritized in subsidy allocation decisions in several countries, and constitute a block exemption under the EU competition law. There is some evidence (e.g., Branstetter and Sakakibara 2002) that RJVs have the stated beneficial effects in enhancing spillovers and R&D efforts. There is however also evidence that RJVs are primarily motivated by cost sharing (Röller, Siebert, and Tombak 2007) and may lead to product market collusion (e.g., Duso, Röller, and Selde-slachts 2014).

2.3 Policies for Innovation

We begin this section with a discussion of the role of (higher) education in innovation policy. We then proceed to basic research and taxation before concluding with discussion of other policies for innovation.

2.3.1 Education

There is rather little robust empirical evidence on the relation between education and innovation (which is somewhat surprising given the large literature on causal effect of education on individual wages). One exception is Toivanen and Väänänen (2016) who find a positive causal impact of education on invention. This suggests that indeed, a policy reaction to Jones's (2005) advice of "having more inventors in order to become richer" as a society is to increase investments in (engineering) higher education. Recent research (Aghion et al. 2017b and Bell et al. 2017) suggests that family background affects the probability to innovate both in Finland and the US. Aghion et al. (2017b) demonstrate that these effects to a large extent work out through education, suggesting

that one should further improve access to Finnish (university) education for all irrespective of socio-economic background.

A key insight from innovation research is the skewed distribution of innovative outcomes, with a low median but a high mean value of innovations (e.g. Pakes 1986 and Lanjouw 1998). To us, this seems to call for an education system that generates a wide-skill base and allows different skills to be combined in possibly unexpected ways, i.e., an education system that encourages individuals to acquire a variety of skills and allows individuals with specialized skills to easily match with each other.

It is well known that innovative activity is concentrated geographically and that high-quality universities play a central role in this agglomeration process (see Audretsch and Feldman 1996 for a seminal paper, and Carlino and Kerr 2015 for a survey of the empirical evidence). Top universities contribute to the agglomeration of innovative activity in many ways. One channel is the supply of educated individuals on which innovative activity depends: For example, Moretti (2004) finds a 0.5 percentage point increase in plant-level productivity as the consequence of a one percentage increase in the share of college graduates in the population of a metropolitan area in the US.

As a small open economy, Finland greatly benefits from the knowledge and innovations created elsewhere. While innovation continues to exhibit locational economies of scale also in future, digitalization and modern ICT are making knowledge flows less dependent on geography (Griffith, Lee, and Van Reenen 2011), suggesting a crucial role for education in enhancing absorptive capacity of the countries.

2.3.2 Basic Research

There is plenty of anecdotal evidence of successful private sector innovations that are based on research in government funded laboratories and universities, often without a direct commercial objective in mind (see, e.g., Mazzucato 2013). However, just as in

the case of education, there is little in terms of rigorous causal evidence.¹⁶ Adams (1990) uses US industry-level data to document that scientific knowledge, measured by scientific publications, increases total factor productivity but that the lag from basic research to productivity growth can be long, 20-30 years. Basic research done at high-quality universities is also a source of significant local knowledge spillovers to the private sector (e.g., Jaffe 1989, Breschi et al. 2006, and Carlino and Kerr 2015). As innovative firms seek to benefit from these spillovers, they locate close to universities (e.g., Jaffe 1989, Anselin, Varga, and Zoltan 1997, and Abramovsky, Harrison, and Simpson 2007). This forms another channel through which universities contribute to agglomeration of innovation (Carlino and Kerr 2015). In small open economies in particular, one should not discount the importance of high-quality basic research as a pull-factor of foreign R&D (e.g. Belderbos et al. 2014).

Any government needs to make decisions on how to allocate the resources devoted to basic research. Despite difficulties created by incomplete information, the government may well be in a position to make high-level decisions regarding allocation of resources across different fields of basic research (e.g., health vs. environment). The government should however delegate resource allocation within research fields to its leading experts and allow, through that same system, reallocation across fields as a function of outcomes. Such a bottom-up approach would hopefully lead to a limited number of large, active research centers within each field that would compete against each other for top researches and funds. This should not only improve the quality of basic research but also seed up commercialization of that research (Goldfarb and Henrekson 2003).

¹⁶ Sveikauskas (2007) offers a survey of the scant literature, and Akcigit, Hanley, and Serrano-Velarde (2017) and Hausmann (2017) recent contributions.

2.3.3 Taxation

Good (corporate) taxation (see Mirrlees et al. 2011) minimizes negative effects on welfare and economic efficiency, has low administrative costs, is distributionally fair and transparent. In cases where production or consumption of goods and services is associated with large externalities, it is theoretically justified to make exceptions to these principles. However, in practice corporate tax incentive schemes tend to become complex and unpredictable and increase tax planning and avoidance (see Mirrlees et al. 2011).¹⁷ If tax incentives are used as an innovation policy tool they should be simple, and focused on innovation or their financing incentives directly. As concluded by the European Commission (2013) and Rouvinen and Takalo (2013), it is therefore much easier to justify, say, R&D tax credits rather than, say, IPR boxes from an innovation policy point of view.

Just as there is evidence of countries competing in terms of the level of corporate taxation (Devereux, Lockwood, and Redoano 2008), they are also likely to use various R&D incentives for the same purpose. In particular, competition for intellectual property revenues is tempting since intangible assets are relatively easy to reallocate from one location to another based on tax considerations (see, e.g, European Commission 2013, Griffith, Miller, and O'Connell, 2014, and Alstadsæter et al., 2015). Mohnen, Vankan and Verspagen (2017) find that firms report higher R&D investments after they start to use an IPR box. Yet, this finding does not mean that the level of innovation in the country or its welfare would increase or that an R&D tax credit would not be a superior instrument to an IPR box. In our view, introduction of IPR boxes at best amounts to a Prisoner's Dilemma - game among countries where the detrimental Nash equilibrium should be avoided by international cooperation (see Rouvinen and Takalo 2013).

¹⁷ For example, in Finland corporate taxation changes almost annually (e.g., R&D tax credits were in force in 2013-2014, and business angel tax relief was introduced for years 2013-2015).

In contrast, tax competition for innovative corporations and individual inventors might be more relevant for Finland: Danish evidence (Kleven et al. 2014) suggests that small open economies with relatively homogenous populations may benefit substantially from tax schemes that give temporary preferential treatment to foreign high-skilled individuals. Akcigit, Baslandze and Stancheva (2016) find that top-inventors are sensitive to top income tax rates in choosing where to locate. Taxation of individual inventors should also affect their incentives and individuals' career choices. The location of innovative corporations and inventors also matters because of their potential to create spillovers (in contrast, the location of IPRs can hardly be a source of positive spillovers directly).

Similarly, the effects of (average) corporate taxation are larger at the extensive margin than at the intensive margin: the possibility to make money is one of the key drivers of (high-growth) entrepreneurship (Lerner 2009a and Isenberg 2013). The example of earlier successful entrepreneurs and their role as business angels may be vital in the creation of a culture of entrepreneurship and risk-taking. However, a large gap between corporate and personal tax rates is conducive for tax planning and avoidance efforts.

2.3.4 Other Policies for Innovation

Besides the policies listed above there is a variety regulatory policies that have a significant impact on innovative activity. We discuss briefly here some selected regulatory policies.

Competition policy is an important part of an innovation infrastructure (Encaoua and Hollander 2002, Segal and Whinston 2007, and Shapiro 2012), and growth models show how competition, firm entry and exit shape innovative activity (Aghion et al. 2005, Acemoglu et al. 2017). According to an extensive literature, there appears to be an inverse-U relationship between market structure and innovation activity created by

two opposing forces: On the one hand, competition is bad for innovation since it reduces the returns to successful innovation; on the other hand, competition is conducive for innovations since it forces the firms to innovate so as to escape competition.¹⁸ This suggests that liberalization of protected and regulated industries might promote innovation. Intensified competition in an upstream industry may also increase innovation in a downstream industry. For example, liberalization of the financial services sector not only generated frantic innovation in the industry itself but also increased innovation in the real sector (Amore, Schneider, and Zaldokas 2013 and Chava et al. 2013).¹⁹

Trade policy matters for innovation for several reasons. Trade stimulates higher productivity, e.g. through increased specialization, greater competition, higher quality intermediate inputs, larger market size, and reallocation away from less productive firms (see, e.g., Bloom, Draca, and Van Reenen 2016, and Samson 2016). Countries that are open to trade will reap a larger part of international knowledge spillovers and the potentially greatest benefit of innovation investments made elsewhere: new goods and services. While these findings are uncontroversial, they do not automatically justify prioritization of exporters in innovation policy making. We also need to understand much better what shapes international knowledge flows. For example, cultural aspects such as ethnicity may shape international knowledge flows (Kerr 2007).

In general, the beneficial effects of enhanced competition and trade openness on innovation appear to be the largest in countries like Finland where firms are closer to technological frontier and where corruption does not distort competition (Dabla-Norris, Ho, and Kyobe 2013 and Aghion, Akcigit and Howitt 2014).

¹⁸ The classic references are Kamien and Schwartz (1975) and Aghion et al. (2005). Kilponen and Santavirta (2007) document the existence of the inverse-U relationship in Finland. However, Hashmi (2013) finds a negative relationship between the intensity of competition and innovation in the US.

¹⁹ Some financial innovations contributed to the emergence of the recent global financial crisis, providing an example of associated with some innovations (cf. footnote 4).

From the innovation policy point of view, well-functioning *labor markets* would encourage risk taking and reallocate labor from declining industries and regions to rising ones. Also the efficiency of direct innovation policy tools may depend on the functioning of labor markets. For example, R&D subsidies and tax credit may affect only the wages of R&D personnel if the supply of R&D personnel is inflexible. (e.g., Goolsbee 1998 and Wolff and Reinthaler 2008).

Unfortunately, the empirical literature on the relation between labor market regulations and innovation is rather unsettled. On the one hand, the Danish-type flexicurity with relatively weak employment protection but relatively high unemployment benefits might be particularly conducive for start-up formation and radical innovation. On the other hand, weak employment protection may deteriorate employees' incentives to innovate in established corporations (see, e.g., Acharya, Baghai-Wadji, and Subramarian 2013, Bozkaya and Kerr 2013, and Griffith and Macartney 2014 for different results).

As indicated in Section 2.3.3, the Danish evidence (see, Kleven et al. 2014) also suggests that immigration policies targeted to attracting innovative individuals can be successful innovation policy tools.

Financial market imperfections constitute another main rationale for an active innovation policy. R&D activities are inherently opaque, human capital intensive, and involve soft information. As a result, innovative start-ups have difficulties to access to outside finance due to informational asymmetries and lack of collateralizable assets (Hall and Lerner 2010 and Kerr and Nanda 2015).

It is notoriously difficult to identify the existence of such financial constraints (see Hall and Lerner 2010 for various empirical strategies): the fact that some firms suffer from lack of finance may just indicate the financial markets work as they should, and are denying funding of bad projects. Furthermore, even in theory it is difficult to identify the right policy response to these financial market imperfections: informational

asymmetries may even lead to *overfinancing*, which would call for a punitive taxation of start-up finance (e.g., de Meza and Webb 1987, Boadway and Keen 2005, and Takalo and Toivanen 2013).²⁰ Despite these challenges, two broad conclusions emerge. First, bank lending remains an important source of outside finance, even for start-ups (Robb and Robinson 2014, and Kerr and Nanda 2015) and innovation (Amore, Schneider, and Zaldokas 2013, Chava et al. 2013, and Nanda and Nicholas 2014). Bank lending and associated credit constraints are also procyclical (Aghion et al. 2012).

Second, the evidence suggests that private sector equity investing is conducive for innovation (Hall and Lerner 2010 and Kaplan and Lerner 2010). Equity investors have both incentives and human capital for ex ante screening, interim monitoring and value-enhancing advice. Furthermore, because innovative investments are complex and risky, optimal financing contracts become complex, too: investors need to have both a share of upside returns in case of a success and control rights in case of a failure (Kaplan and Strömberg 2003). Whether private sector equity financing markets work efficiently or not appear to matter more for countries close to technological frontier, such as Finland (Aghion and Mayer-Foulkes 2005 and Dabla-Norris, Ho, and Kyobe 2013).

Based on these conclusions, there seems to be a case for policies that improve early-stage equity financing in Finland. The right policy can hardly be based on public equity investing in commercial projects. Rather, one should create the right environment for private sector equity investors. To the extent there is need for direct public innovation finance beyond R&D subsidies, the public sector should not mimic private innovation finance but invest differently, operating when liquidity in financial markets dries up and focusing on projects where the ratio of social returns to private returns is high.

²⁰ As illustrated by the dot-com boom and bust at the turn of the millenium, and the recent global financial crisis that begun from the US subprime mortgage markets, this kind of overfinancing is not just a theoretical curiosity, and may have severe macroeconomic consequences.

Besides the many issues discussed above (e.g., taxation, education, basic research, and labour markets), the legal environment matters for private sector investors. For example, Hyytinen, Kuosa and Takalo (2003) argue that a strengthening of the Finnish investor protection legislation enhanced the role of equity finance in the Finnish corporate finance environment.

As we have emphasized, identifying the right policies to improve legislation is not easy. For example, while a lenient *bankruptcy legislation* clearly encourages entrepreneurial risk-taking by reducing the cost of failure, it also discourages financing of entrepreneurship. The evidence on which of the two opposing effects dominates remains inconclusive (see, e.g, Acharya and Subramanian 2009, and Cerqueiro et al. 2017, for conflicting results) and likely depend on the institutional context. Koskinen, Korkeamäki, and Takalo (2007) find that weakening of strong creditor rights in corporate bankruptcy in Finland boosted corporate investments and firm valuations, but they did not study the effects on innovation.

3. Overview of Innovation Policy in Finland

This section discusses recent developments in and the current state of Finnish innovation policy, with a focus on four tools in particular.

First, government funds directly public research universities and research institutes. Although the organizations decide on the use of these funds independently, they are incentivized by the university financing model and performance agreements. As university finance is covered in a separate report by Hannu Vartiainen, we focus on public research institutes.

Second, the Finnish government offers selective funding to public and private R&D projects, in the form of grants, loans, and equity investments. These are not directly distributed by the government, but through intermediary institutions such as Tekes

and the Academy of Finland. We provide a counterfactual evaluation of the welfare effects of Tekes's activities in Section 4.

Third, the government may offer tax incentives for R&D. There have been at least two temporary innovation-related tax credit programs in Finland over this decade: R&D tax credits and a business angel tax deduction. We provide a counterfactual welfare evaluation of the Finnish R&D tax credit regime in Section 4.

Fourth, the government sets intellectual property rights (IPRs). The legislation concerning IPRs is largely derived from the European Union level but there is some national discretion in interpretation and implementation.

In addition to these there are some smaller programs concerning innovations directly, and numerous larger policy areas which have an indirect effect on innovation. An overview of these policies in Finland is beyond the scope of this report.

3.1. Public Sector Research Institutes

There are currently 12 public research institutes operating under different ministries. The direct budget funding for these institutions in 2017 was 195.2 million euros (m€). The largest recipients of the funds are VTT Technical Research Center (73.5 m€), Luke Natural Resources Institute (48 m€) and THL National Institute for Health and Welfare (22.2 m€).

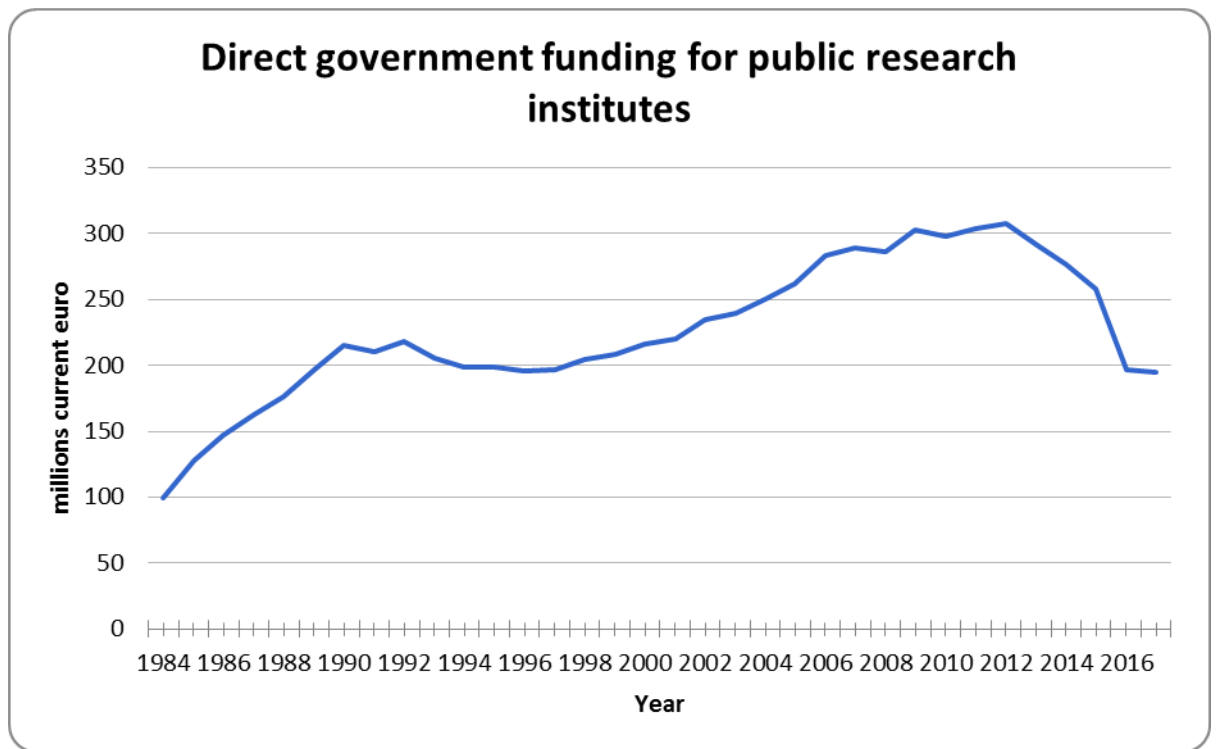


Figure 2. Direct government funding for public research institutes 1984-2017. Source: Statistics Finland: Government R&D funding in the general government budget.

The previous Finnish Government (Finnish Government 2011) initiated a reform of public research institutes. The reform induced three major changes. First, in total 70 million euros (subsequently reduced to 55.6 million) was assigned for the new Strategic Research program, which is administered by the Academy of Finland but with the research themes set by the government. A smaller sum, 12.5 million, was directed to the Prime Minister’s Office for commissioning reports to support policymaking. The funding for the new programs was mainly obtained by redirecting funds from the public research institutes, as indicated by Figure 2: the budgets of the research institutes were cut in total 65.5 million according to their (budgetary) size. In addition, the budgets of the Academy of Finland and Tekes were cut by 10 and 7.5 million, respectively.²¹

The second change was that some institutes were merged together, and others merged into universities. An open question, possibly driving the restructuring, is to what

²¹ All figures correspond to 2017 and are derived from the appendix of Prime Minister’s Office Finland (2013).

extent limited resources should be allocated to public research institutes instead of universities where research and teaching are interlinked. The third reform sought to increase the coordination of different ministries' commissioning of research.

While the new Strategic Research Program is an example of the top-down approach praised by Mazzucato (2013) and criticized by the standard economics approach, it is top-down to a lesser degree than public research institutes are. In the research conducted by public research institutes, both the agenda and the organizations responsible for the research are set by the Government. The new program continues to fix the agendas but the organizations carrying out the research are chosen by a competitive process. This argument, however, does not apply to the shift from funding from the Academy of Finland and Tekes and in these cases the new programs represent a move towards a more top-down approach. One can also argue that the administration of the Strategic Research Program by the Academy of Finland may compromise the Academy of Finland's objective to fund basic research based on merit rather than on topic. One may further worry that the topics of the new program are narrower than the objectives of the research institutes, meaning a tighter top-down guidance of research from this respect.

Perhaps the major drawback of the new programs is the wasteful duplication of investments created by the competitive process. Kultti, Nurminen and Tukiainen (2015) estimate that mere application costs for the first funding round of the Strategic Research Program amounted to 3.3 million euros.

3.2 Selective Public Funding of R&D

3.2.1 Grants and Subsidized Loans

Publicly financed R&D grants and subsidized loans for R&D in Finland are almost entirely distributed via the Academy of Finland and Tekes. Broadly speaking, Tekes grants both grants and subsidized loans to applied research and the Academy of Finland allocates grants to basic research. Figure 3 shows the development of government funding for research and innovation distributed through the Academy of Finland and Tekes. The funding by the Academy of Finland has continued to increase also over the recent years, after a drop in the early 2010s. The recent Academy of Finland's budget increases have, however, come wholly in the form of earmarked funds with a stringent government control, with the level of non-earmarked funds decreasing slightly. In 2017 the earmarked funds are directed to ICT programs (10 m€), research infrastructures (10 m€), university profiling (50 m€), the Young Researchers-program (10 m€) and the Strategic Research program (55.6 m€), discussed in Section 3.1. Altogether these earmarked funds amount to over 150 million euros and over a third of the Academy's budget. In 2012, practically all funds were non-earmarked.²² In this sense governmental control over the Academy has increased markedly in recent years.

Tekes' mission is to promote *the development of industry and services by means of technology, innovations and growth funding. This helps to renew industries, increase value added and productivity, improve the quality of working life, as well as boost exports and generate employment and wellbeing*".²³ As shown by Figure 3, the appropriations for Tekes reached their zenith in 2010, and the budget reductions have been quite drastic since 2014.

²² Excluding some membership fees of international organizations and participating in EU research infrastructure programs.

²³ <https://www.tekes.fi/en/tekes/strategy/>, last accessed on 7 December 2017.

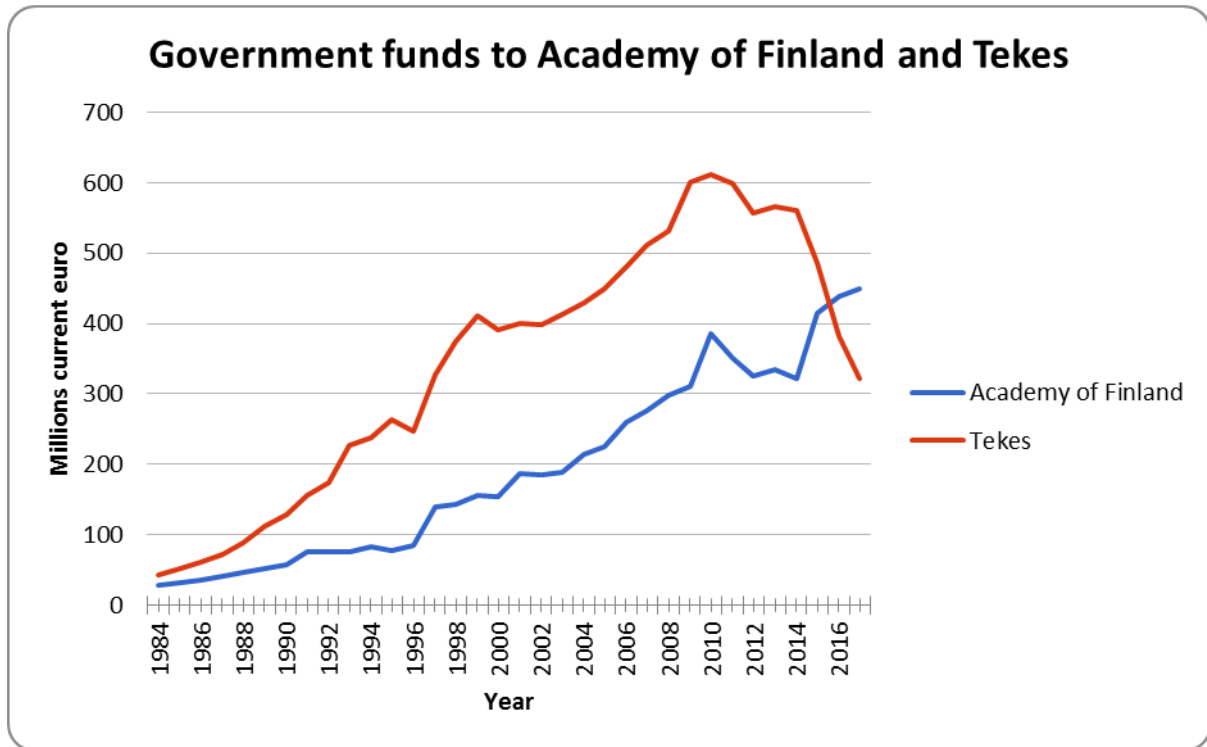


Figure 3. The development of government funding to Academy of Finland and Tekes 1984-2017. Source: Statistics Finland: Government R&D funding in the general government budget.

The main policy tools of Tekes are grants and subsidized loans, which are both granted based on applications. After receiving an application, a team of Tekes' experts reviews and grades it in several dimensions. The screening stage includes a thorough interview with the applicant's representatives. The expert team then makes a funding proposal for a funding committee, which decides on funding.

Loans are granted for development and piloting to cover 50-70% of project costs at a fixed interest rate, currently standing at one percent. If the project fails to produce commercial output, the loan can partly be transformed into a grant. Grants are available for research and creation of new knowledge and they cover up to 80% of the business R&D project costs. Tekes has a priority for funding R&D by small and medium-sized enterprises (SMEs), although large companies can also get funding from Tekes. For example, SMEs can get 5-10 percentage points higher grants than larger companies.

The use of loans in Tekes' policy tool mix have increased significantly both absolutely and relative to grants (see Figure 4). In particular, grant appropriations have been significantly cut since 2011 whereas loan appropriations have continued to increase.

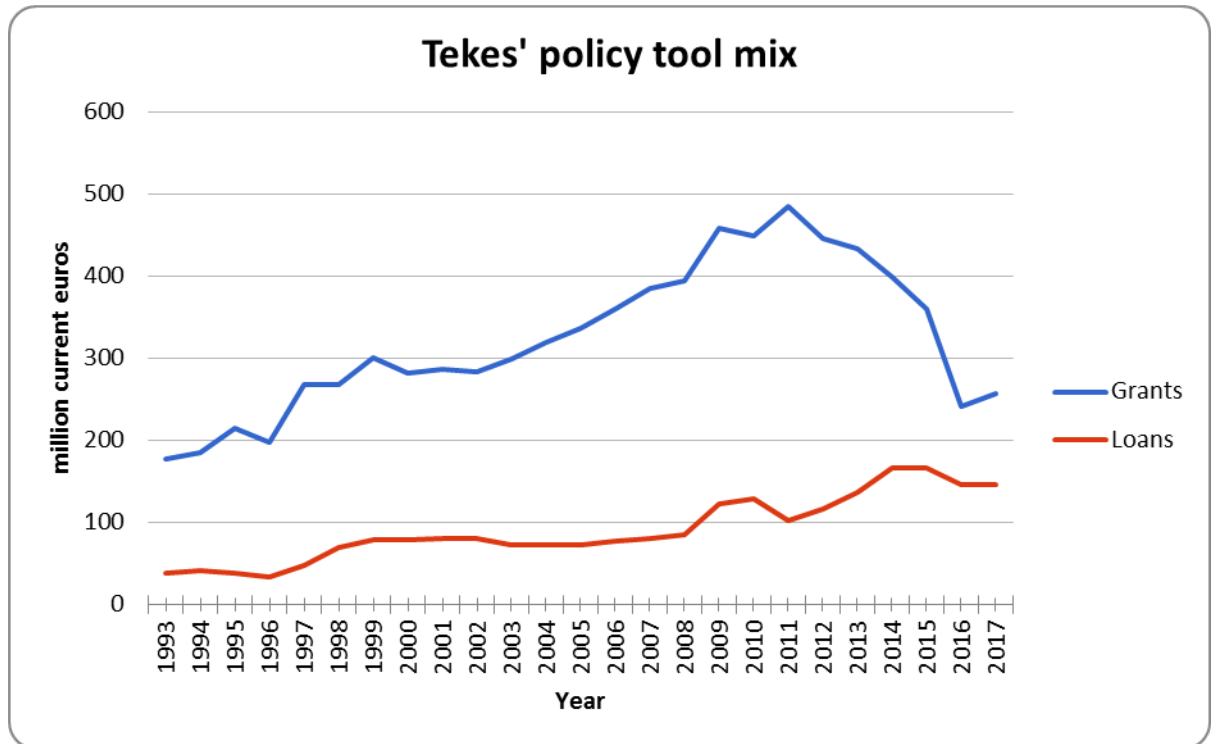


Figure 4. Development of Tekes' grants and loans. Source: Tekes, Tekes Financial Statements, General government budget, authors' own calculations. 1993-2017. The sums depict Tekes' authorized budget, not necessarily realized amounts. Government key projects for 2016-2019 are not included. The aggregate may not correspond to that in Figure 3 because of different statistical concepts.

Tekes' grants are awarded to both public and private sector research. Figure 4 shows how Tekes' funding to the public sector has followed tightly funding to the private sector, being only little smaller, but in 2016 the share of the public sector decreased drastically and is now below 40 % of all grants.

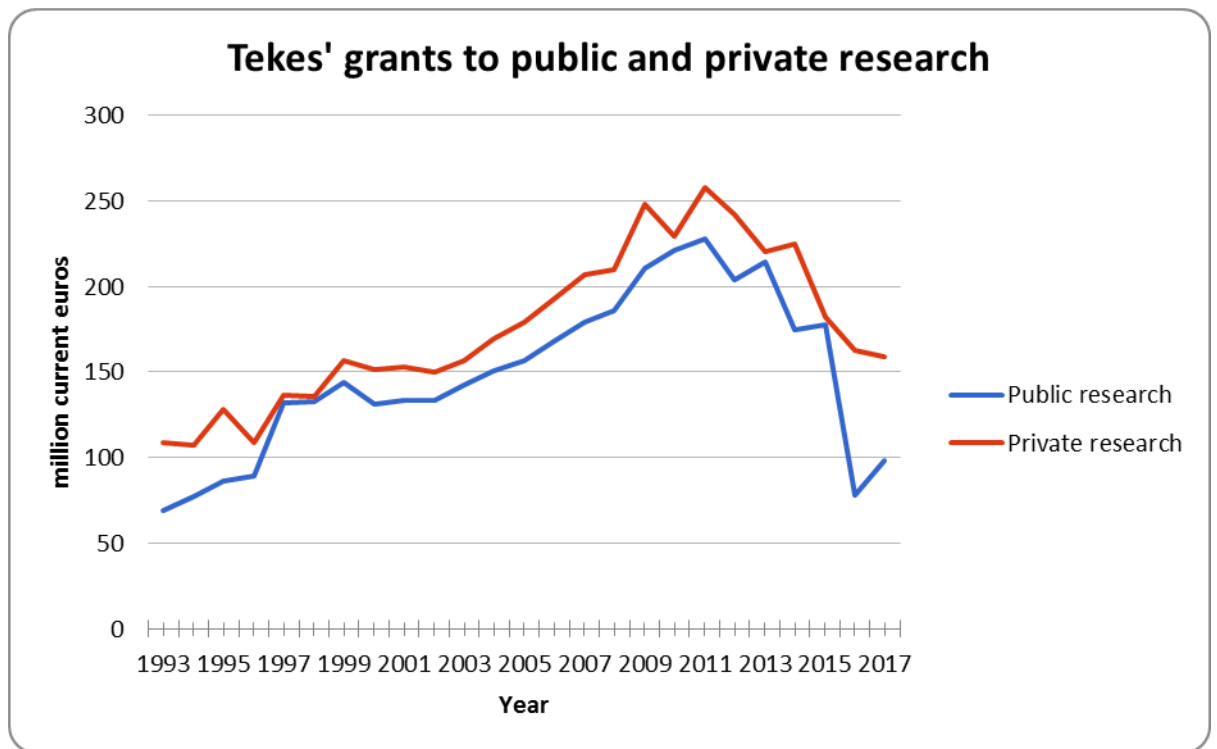


Figure 5. Development of Tekes' grants by sector. Source: Tekes, Tekes Financial Statements, General government budget, own calculations. 1993-2017. The sums depict Tekes' authorized budget, not necessarily realized amount. Government key projects for 2016-2019 are not included. The aggregate may not correspond to that in Figure 3 because of different statistical concepts.

Besides the Academy of Finland and Tekes, there are various other public sector instances providing funding for innovation (some of the public sector equity financiers are covered in the next subsection). For example, at least the city of Helsinki has its own innovation fund. The fund was established in 2002 and has since financed different projects and the operation of Forum Virum, an innovation-promoting company owned by the city, with 38 million euros (City of Helsinki 2015). The myriad of innovation fund organizations has been criticized by previous evaluations of the Finnish innovation policy (see, e.g., Georghiou et al 2003, and Veugelers et al. 2009).²⁴

²⁴ In total the Finnish government supported private business by 4136 billion euros in 2016 (National Audit Office of Finland 2017). Besides support for R&D, the figure includes all other support which is allowed by the EU directives.

3.2.2 Equity Investments

The Finnish government is also involved in encouraging innovation through equity markets. There are several public sector equity investment organizations in Finland, with different but partially overlapping focuses. For example, Tesi (Suomen Teollisuussijoitus Oy) invests in companies both directly and through funds. At the end of 2016 Tesi had 336 million euros invested in equity funds and 189 million euros as direct investments. Although Tesi was founded in 1995 primarily as a fund investor, in recent years government has emphasized direct investments over fund investments (National Audit Office of Finland 2016).

Tesi's focus is on supporting more mature companies, and promoting innovation is not its sole aim. In the supplementary budget of 2009 it was given 100 million euros to support export companies as a business cycle measure (Government bill 1/2009), and in the 2012 supplementary budget it was given 30 million euros to "strengthen government's participation in the mining industry's value chain" (Government bill 23/2012).

The programs closest to innovation policy are KRR I and KRR II, which are "funds of funds", i.e., they invest in private equity funds. Tesi's investments in these two funds total 114 million euros. Plans are underway for KRR III.

The law requires Tesi to be profitable, however also stating that higher risk or lower return than usual can be accepted in individual investments to fulfill the societal objectives of the fund (§2 of "Act on Government-owned Investment Company Tesi" 1351/1999).²⁵ Historically Tesi's returns have been modest, with a return on equity of 1% and a return on investment of 2% for 1995-2014 (National Audit Office of Finland 2016).

Another important public sector equity investor is Tekes Venture Capital, which was founded in 2014. This was part of a reorienting of public early-stage equity invest-

²⁵ Translations of Acts and Degrees from Finnish by the Authors in case no official translation exists.

ments from direct investments to fund investments. According to the Report by the Commercial Committee of the Finnish Parliament (25/2013), this would be a more efficient way of developing private equity markets. Tekes Venture Capital's realized investments and unfunded commitments amounted to 44.1 million euros at the end of 2016.

Tekes Venture Capital is not required by law to make profit (§4 of "Act on Government-owned Company Investing in Early-Stage Equity Funds" 967/2013) and it accepts arrangements with asymmetric profit sharing in favor of private investors. Sitra is yet another public fund, but it operates directly under the parliament, with over 700 million euros in equity. Prior to the founding of Tekes in 1983, public financing of private R&D had been the responsibility of Sitra and the Ministry of Trade and Industry. After 1987 Sitra began to promote the establishment and development of private equity markets in Finland. Through its history Sitra has made over 560 million euros worth of private equity investments directly and through funds, with the return on these investments being negative overall and fund investments producing a better return than direct investments. Sitra is required to be financially self-sustainable as its operations are funded with endowment capital and returns from capital investments.

In the 2000's the role of private equity investments in its strategy has diminished. The number of direct investments peaked in 2001, and no direct investments have been made to new companies since 2015, although some companies have received additional investments. In 2016 Sitra had direct investments of 75 million euros (valued at 10 million euros) and fund investments of 63 million euros (valued at 39 million euros).

Besides Tesi, Tekes Venture Capital and Sitra, there are several other public sector equity investors such as Finnvera and VTT Ventures. Ylhäinen (2013) provides causal evidence of Finnvera's investments, finding positive effects on employment but negative effects on productivity. Given these results, Finnvera's investments cannot be

considered part of successful innovation policy, but they may have some other, non-innovation policy objectives.

In the light of the received economic approach to innovation, the recent changes in the government equity investment strategies are mixed. First, while there is probably room for a countercyclical early stage government venture capital investments in innovative companies, the government's later-stage equity investments, especially to non-innovative companies, are not easily justified.

Second, direct equity investments can only be supported by a particularly strong need to resort to a top-down approach; in contrast to subsidies and soft loans, equity investments allow for gaining control in invested companies. Thus direct equity investments by the government cannot be easily justified if the alternative is to use subsidies or invest indirectly via funds of funds. In contrast, indirect investments via funds of funds can be justified. Compared to selective funding via subsidies and loans, the advantage of indirect investments via funds of funds is that it leaves the selection of investments to private sector experts and the disadvantage is that the investments cannot be directed to projects where the ratio of social to private returns is particularly high. Since private returns and consumer surplus are positively correlated, the indirect investments via funds of funds would be justified if imperfect appropriation of consumer surplus or financial market failures are the key reason for policy intervention. However, if the main reason for policy intervention are technological spillovers, then investing via the private sector is questionable as the private sector makes its investment choices based on expected profits, not technological spillovers.

In our opinion, there is a need to evaluate the operations of Sitra, Tesi and Tekes Venture Capital by using modern microeconomic techniques of policy evaluation. Financial self-sufficiency, profitability, and standard returns to investments are not a good measure of the efficacy of the governments investments; according to the standard

economic approach to innovation, the government should invest in areas where appropriability problems dilute returns to investments and hence there is underinvestment. As also pointed out by Lerner (2009a), the creation of active entrepreneurial and venture capital environment takes time, and financial self-sufficiency and short-run profitability requirements on government venture capital investments may backfire.

3.3 Tax Incentives

Finland is among the minority of developed countries with no R&D tax incentives (OECD 2017). There have been, however, two temporary programs in recent years: an R&D tax deduction in 2013-2014, and a business angel tax deduction in 2013-2015. This section discusses these two programs and their design. Our evaluation of the R&D tax credit program is postponed to Section 4. It appears that the take-up of both programs fell significantly short of government's initial expectations.

3.3.1 R&D Tax Deduction of 2013-2014

The Finnish R&D tax credit was short-lived but long in the making. For example, the Ministry of Economic Affairs and Employment supported the introduction of an R&D tax credit in 2009 (Ukkola, Hintsanen, Kuivisto, Viitanen 2009, Section 5), whereas, e.g., the Working Group for Developing the Finnish Tax System (Ministry of Finance, 2010, pp. 25) took a negative view.

Nonetheless, the Minister of Economic Affairs and Employment, Mauri Pekkarinen, began to push for an R&D tax credit. A public investigator nominated by the government, Jorma Eloranta (a leading industrialist in Finland), supported the introduction of an R&D tax credit and a lowering of the corporate tax rate from the then prevailing rate of 24.5% to 20% in February 2012 (Eloranta 2012). In December 2012 the government announced and passed a bill (Government bill 175/2012) allowing businesses

to deduct their R&D wage expenses from their income. The program was initially set to be in place until 2015, but in the spring of 2013 the duration was cut by one year. The R&D tax deduction allowed companies to deduct R&D wage expenses fully up to 400 000€ annually, with a minimum of 15 000€. However, firms could only make the extra deduction of R&D wage expenses from projects whose wage bill had not been supported by an R&D subsidy (from Tekes or from some other organization). Projects conducted by a firm in financial distress or in cooperation with a research organization (e.g., a university) were also ineligible. The expenses of a project were eligible only if the project was started no earlier than January 1st 2013 and the expenses had been incurred by December 31st 2014. Unlike some other countries' R&D tax credit schemes, the Finnish scheme only allowed loss-making firms postpone the use of the tax credit to later years without a possibility to receive an immediate transfer.

The introduction and implementation of the Finnish tax credit regime can be criticized. The tax credit law of 2012 was rushed through the Parliament in such a hurry that the Members of Parliament of Pekkarinen's own party (Centre Party) submitted an official protest in the Parliamentary Committee for Finance. While the industry in general welcomed the tax credit, it, too, criticized the haste at which the law was introduced. The labor unions raised the concerns i) of how the wages that are eligible for the credit would be identified, ii) of the tax code becoming more complicated, iii) of the temporary nature of the law; iv) and of the inability of loss-making firms to immediately gain from the credit (as opposed to being able to defer the credit to later years).²⁷ Government's decision in 2013 to shorten the period of the tax credit regime from three years to two was driven by the simultaneous decision to lower the corporate tax rate from 24.5% to 20% and was motivated by the aim of broadening the corporate income tax

²⁷ For the industry viewpoints, see, e.g., <https://ek.fi/ajankohtaista/hyotytietoa-yrityksille/2012/12/17/uudet-verokannusteet-yritysten-tk-toimintaan-ja-riskipaaoman-hankintaan/>, last accessed on 6 November, 2017.

base (Minutes of the Parliamentary Finance Committee VaVM 32/2013 and Government bill 185/2013). We were unable to find negative comments on the abolishment of the R&D tax credit.

Kuusi et al. (2016) note that even though the program was temporary, it failed to incorporate a research setting that would enable identification of its causal effects. Kuusi et al. (2016) find that only some 800 firms took advantage of the Finnish tax credit scheme, and that larger and older companies which also received direct R&D subsidies were more likely to apply for the deduction. This was in contrast to the program's stated goals of targeting the existing innovation policy framework's blind spots.

3.3.2 Business Angel Tax Deduction of 2013-2015

The Finnish Business Angel Network FIBAN made a proposal for a business angel tax deduction in February 2012. The government adopted this model and the bill (Government bill 177/2012) was passed in December of the same year. The purpose of the bill was to increase the transfer of equity and knowledge capital into startups.

This scheme allows individual investors to deduct their financial investments into small companies from their capital income gained during the tax year the investment was made, or during the following three years. Thus the program is still in place from the investors' point of view as the last deductions can be made from 2018 capital income. The capital income tax is, however, only postponed, as the investment will be deducted from the acquisition price when realized.

The Government bill (177/2012) estimated that the program would decrease tax revenue by 12 million euros each year during 2013-2015, although this would be recouped later. Depending on whether the marginal capital tax rate used in the calculation is 30 or 32 percent, the expected revenue loss implies expected investments worth 37.5-40 million euros in total. The realized amount of investments was 4.2 million euros (Finnish Tax Administration, n.d.).

While encouragement of business angel activity in Finland may be justified, this tax credit program would warrant an evaluation of its costs and benefits to the society.

3.4 Intellectual Property Rights

National discretion in the IPR policymaking is limited, with much of the legislation deriving from the EU and (other) international agreements such as the Trade Related Aspects of Intellectual Property Rights. Since boundaries of intellectual property rights are inherently imprecise, however, there is discretion in the case of implementation and interpretation of the cross-border agreements and legislation, and the case law also matters in this area. Naturally the Finnish policy makers can also attempt to influence international agreements and EU legislation. Furthermore, there is considerable national discretion in the boundaries of IPR legislation with other legislation, such as employment contracts. For example, the default ownership of university inventions in the case of contract research were transferred from individual researchers to universities in 2007. Ejermo and Toivanen (2017) find that this change in the IPR regime had adverse consequences on innovation in Finland, as the same change has also had in other countries (see, e.g., Czarnitzki et al. 2015 and Hvide and Jones 2015).

As discussed in Section 2, the main intellectual property rights are patents and copyrights. The Ministry of Economic Affairs and Employment is responsible for patent policy and the Ministry of Education and Culture for copyright policy. The attempt to harmonize IPR policy making and transfer copyrights to the Ministry of Economic Affairs and Employment failed under the Vanhanen II Government.

National policy makers can impact patent policy, e.g., via setting the incentive structure of the patent and trademark office. Economic theory suggests that it would be optimal to wipe out low quality patent applications and low value patents by setting strong incentives for patent examiners to reject patent applications and by setting high patent application and renewal fees. Since one purpose of the patent system is to dis-

seminate information, it would be also optimal to facilitate the use of patent information.

A cross-country comparison of patent system quality by de Saint-Georges and van Pottelsberghe de la Potterie (2013) suggest that the Finnish patent system works fairly well from a welfare point of view. De Saint-Georges and van Pottelsberghe de la Potterie (2013) report large variation between EU countries, with Nordics (including Finland) and UK having high-quality patent systems and Greece, Germany and Spain being in the “medium-low” category, alongside Australia, Singapore, Brazil, Thailand and Mexico. The authors find that higher-quality patent systems receive a lower number of patent applications, with non-resident applicants being more responsive to patent system quality than resident applicants. Although descriptive, this evidence is consistent with a more stringent and a transparent patent process discouraging patent applications. The authors note that this may bias national patent count metrics, as a country may receive more patent applications not because of its innovative capacity but because of its lax patent process.

The Unitary Patent and the Unified Patent Court that has been agreed upon by the EU member states and is expected to become operational during 2018 will further significantly limit possibilities for national patent policy-making. While the Unitary Patent and the Unified Patent Court will simplify patent application and enforcement processes in the EU, they will also render patents more cost effective. According to received wisdom (see, e.g., Jaffe and Lerner 2004 and Bessen and Meurer 2008), this is likely to be detrimental for the EU welfare, albeit the implications for a small open economy like Finland are unclear.

Copyright policy has been heatedly debated in Finland over the past decades. A contested reform of copyright law entered into force in 2005. A Citizens' Initiative to re-

voke parts of the law was successfully submitted to the Finnish parliament on 26 November 2013 but failed to gather sufficient support at the Parliament.

As mentioned in Section 2, many innovation policies are vulnerable to lobbying and copyright policies in Finland constitute an apt example. According to *Helsingin Sanomat* (Helsingin Sanomat 5.5.2013), the Finnish Parliament dealt with copyright legislation 67 times during the years 1997-2013. In these discussions the Parliament consulted experts from content producers much more often than experts from users.²⁸ Moreover the senior civil servant in charge of writing the law at the Ministry of Education and Culture was a board member of one of the main content producer associations while preparing the 2005 legislation. Consequently the Parliamentary Deputy-Ombudsman gave a warning to the Ministry of Education and Culture (2732/2005) because of the biased preparation of the copyright law.

Park (2008) compares patent protection across countries in 1995, 2000 and 2005 using an index taking values from 1 to 5 with higher values corresponding to stronger patent protection. Looking at the EU15, the index varies little between countries in 2005. Seven of the countries, including Finland, achieve a score of 4.67, the lowest score (Luxembourg) being 4.14. Looking at the change between 1995 and 2005, we see that no country weakened its patent protection. Large changes occur only in Portugal (+1.03), Greece (+0.83) and Ireland (+0.53). The change for Finland over the period is +0.25, slightly higher than the median (+0.13).

World Economic Forum's (WEF) Global Competitiveness Index database includes an index for IPR strength and covers the years 2008-2016. The index takes values from 1 to 7, again with higher values corresponding to stronger IPR. Focusing now

²⁸ According to our preliminary calculations, the Parliament consulted experts from content producers 192 times and experts from users 22 times. In addition the industry representatives from the Confederation of Finnish Industries and Nokia whose interests probably coincide more with content producers than users were consulted 31 times. While our classification of experts to content producers and users is only tentative, the bias towards content producers is clear.

on the EU27 we find that Finland's score is the highest in the group for 2011-2016. There is little change in Finland's index value and the median over 2008-2016, with Finland's value (6.3) being consistently about 1.6 points higher than the median.

The International Property Rights Index by the Property Rights Alliance is largely based on Park's and WEF's indices, and therefore echoes their findings; Finland has (one of) the strongest IPR regimes in the world.

In Section 3.2 (see also Takalo and Toivanen 2016) we argue that a weak IPR regime combined with tough patent examination process might be optimal to a small open economy like Finland. From this perspective it is questionable whether being at the top of the IPR indices is in the national interest of Finland. While the Unitary Patent and the Unified Patent Court will further significantly reduce the national discretion in the area of patent policy, there is still discretion in the area of copyrights. In enacting IPR legislation, more attention should be paid to the political economy considerations and hence emphasize the view point of users more. More generally the Finnish Council of Regulatory Impact Analysis has pointed out that the analysis of economic impacts of the government proposals for new legislations is often inadequate (Hyytinen ja Moisio 2017). Since IPRs matter for innovation and growth, careful *ex ante* and *ex post* analyses of the economic effects of the Finnish IPR legislations would certainly be welcome.

4. Welfare Evaluation of the Finnish R&D Subsidy and Tax Credit Policies

In this section we present the results from our analysis of the Finnish R&D subsidy policy, and of the Finnish R&D tax credit policy that was in place 2013–2014. Those subsidy and tax credit policies are outlined in Section 3, and details of our analyses can be found in TTT (2017) and in Takalo and Toivanen (2017). We begin by reporting the results of our theoretical analyses of the Finnish R&D subsidy and tax credit policies in Subsection 4.1. We briefly summarize the data we use in Subsection 4.2. In Section 4.3

we summarize our counterfactual welfare analysis of the Finnish R&D subsidy and tax credit policies.

4.1 Theoretical Results

4.1.1 The Finnish R&D Subsidy Policy

In TTT (2017) we develop a model of the R&D subsidy process with incomplete information, financial market imperfections, imperfect appropriability of R&D, and endogenous R&D participation. There we theoretically characterize the optimal subsidy policy by a government agency such as Tekes allocating targeted R&D subsidies. We find that the subsidy rate should be higher, the larger the externality generated by R&D. At the extensive margin the subsidy rate should be higher, the higher the fixed cost of R&D, but at the intensive margin the fixed cost is by definition irrelevant.

We find that the financial market imperfections translate into higher cost of external private sector funding of the firms. From the point of the view of the subsidy-granting agency this means that the firm's R&D technology becomes less effective and hence, it should be allocated a smaller subsidy rate at the intensive margin and a smaller (= zero) or a larger subsidy rate at the extensive margin. Our theoretical analysis thus suggests that the use of financial market imperfections as a reason to allocate large subsidies is not necessarily warranted.

4.1.2 The Finnish R&D Tax Credit Policy

The Finnish R&D tax credit scheme of 2013-2014 allowed companies to deduct R&D wage expenses fully up to 400 000€ annually, with a minimum of 15 000€. In Takalo and Toivanen (2017) we show how these thresholds have the following effects on a firm's R&D investments conditional on the firm being aware of and eligible for the tax credit. First, if a firm's R&D wage bill exceeds the upper limit of 400 000€, the tax credit has no effect on the marginal cost of R&D labor and hence no incentive effect either. Thus, the tax credit scheme is a pure transfer of 80-98 000€ (the applicable cor-

porate tax rate (0.2 or 0.245) times 400 000€) for firms whose R&D wage bill exceeds 400 000€.

Second, the tax credit on R&D wage bills below 15 000€ is zero. If a firm invests exactly 15 000€ into R&D labor and corporate tax rate is 0.245 (as it was in 2013-2014), the firm will receive a tax credit of $0.245 \times 15000 \text{ €} = 3\,675\text{€}$. No firm should thus have invested into R&D an amount between 11 325€ and 15 000€, since the government paid the firm 3 675€ to invest the difference between 15 000€ and the amount the firm would have invested without the tax credit. For firms that would have invested without the tax credit more than 11 325€ (but less than 15 000€), the policy lowers the marginal cost of R&D labor to below zero; for firms that would have invested less than 11 325€, the marginal cost is positive but less than one. At the margin where the firm would have invested 14999 € without the tax credit, the subsidy percent on the marginal euro is 3 675%.

The Finnish R&D tax credit scheme also stipulated that a firm cannot use an R&D subsidy on any of its R&D wage bill if it uses the R&D tax credit. This non-linearity reduces firms' incentive to apply for a subsidy and affect the subsidy decisions of Tekes. If the Tekes optimal subsidy rate in the absence of the tax credit would have been lower than the tax credit rate, Tekes will adjust its subsidy rates for non-wage related expenses downwards, which in turn should further reduce the firm's incentives to apply for subsidies.

4.2 Data

Our data comes from two main sources: from Tekes, we obtained detailed data on all R&D subsidy applications between 1/2000 and 12/2008. These data include the applied amount of funding, Tekes' internal screening outcomes and final funding decisions, the realized project expenses and reimbursements by Tekes. We matched these data to the R&D survey and balance-sheet data from Statistics Finland. After matching this infor-

mation with firm characteristics, we end up with 25 505 firm-year observations for 8 363 firms. We also use cost-of-borrowing data for Finland from the European Central Bank Statistical Data Warehouse.

We show some descriptive statistics in Table 1 (for further descriptive statistics, see TTT 2017 and Takalo and Toivanen 2017). The average age of non-applicant (applicant) firms in our data is 17 (13) years; the average number of employees is 107 (176), and the average sales per employee, normalized to year 2005 in 100 000€, is 0.27 (0.21). Of the non-applicant (applicant) firms in our data, 70% (73%) are SMEs, 17% (20%) are located in the regions eligible for EU regional aid, and 55% (84%) invested in R&D in the preceding year. All these differences between applicants and non-applicants are statistically significant. As the figures of Table 1 also imply, on average some 60% firms invest in R&D and only some 20% of the firms apply for subsidies.

Table 1 also displays descriptive statistics for successful and rejected applicants; the differences are not statistically significant. For those firms that obtain a subsidy, the average subsidy rate is 0.36 with a large standard deviation. The average project level R&D investment over the (max. 3 year) lifetime of a project is 393 000€.

Table 1. Descriptive statistics												
	Non-applicants			Applicants			Rejected			Successful		
Variable	Mean	S.d.	P50	Mean	S.d.	P50	Mean	S.d.	P50	Mean	S.d.	P50
Subsidy rate	-	-	-	0.30	0.27	0.35	0	-	-	0.36	0.25	0.35
R&D , realized	-	-	-	392 902	824 671	151 965	17 511	148 268	0.00	468 932	867 083	201 531
Applicant $t-1$	0.15	0.35	0.00	0.23	0.42	0.00	0.23	0.42	0	0.24	0.42	0.00
R&D $t-1$	0.55	0.50	1.00	0.84	0.37	1.00	0.82	0.38	1.00	0.84	0.37	1.00
SME	0.70	0.46	1.00	0.73	0.44	1.00	0.72	0.45	1.00	0.74	0.44	1.00
Age	16.74	15.65	13.00	12.62	13.21	9.00	13.02	13.26	9.00	12.52	13.20	9.00
# empl.	106.60	262.49	33.00	176.45	612.94	18.00	164.40	494.87	23.90	156.57	510.80	17
Sales/empl.	0.27	0.39	0.14	0.21	0.36	0.11	0.23	0.41	0.11	0.21	0.35	0.11
Region	0.17	0.38	0.00	0.20	0.40	0.00	0.20	0.40	0.00	0.20	0.40	0.00
#Obs.	19 718			5 787			940			4 847		

Notes: Subsidy rate is the fraction of R&D paid by the government. R&D is the actual R&D investment in the project, measured in 2005 euros. Applicant $t-1$ takes value 1 if the firm applied for a subsidy in the preceding and 0 otherwise. R&D $t-1$ takes value 1 if the firm invested in R&D in the preceding year and 0 otherwise. SME takes value 1 if the firm in year t is an SME according to the EU guidelines, and zero otherwise. Age is the age of the firm in year t in years; region takes value 1 if the firm is located in a region eligible for the EU regional aid and 0 otherwise. Observations are at firm-year level. Columns “Rejected” and “Successful” reflect application outcome at Tekes. All differences between non-applicants and applicants significant at 5% level.

4.3 Results from the Counterfactual Analysis

In TTT (2017) we estimate the model outlined in Section 4.1 on the data described in Section 4.2. In TTT (2017) we also describe how we use the model and estimated results to calculate counterfactual welfare effects of various policies. In Takalo and Toivanen (2017) we provide a counterfactual welfare analysis of the Finnish tax credit regime of 2013-2014. Here we report the results from TTT (2017) and Takalo and Toivanen (2017) for the following five scenarios.

- 1) A laissez-faire scenario without any government intervention in firms' R&D investments.
- 2) The first-best policy where the social planner can force the firms to invest the desired amount in each R&D project, even if this means that the firm will make losses. In TTT 2017 and Takalo and Toivanen 2017 we also report the results for the second-best policy where the social planner is constrained by the firms' zero profit condition.
- 3) Subsidies only – regime where Tekes allocates R&D subsidies for firms that apply for them. This is the regime that has prevailed in Finland except for 2013-2014.
- 4) Tax credit only -regime. We calculate the optimal tax credit policy in an environment where it is the only policy tool, and there are no nonlinearities in the tax credit scheme.
- 5) The Finnish tax credit regime that was in place in 2013-2014. That regime introduces tax credits on the top of the subsidy policy.

The reported means are calculated over all firms and simulation draws unless otherwise indicated. We report percentiles of firm-specific means. We use 1.2 for the shadow cost of public funds and 0.2 for the corporate tax rate.

4.3.1 R&D Participation

In Table 2 we report the firms' propensity to conduct R&D in the different policy regimes. Under laissez-faire, 53% of firms invests in R&D in a given year. A quarter of the firms invest less than 13% of the time, the median investment probability over all firms is 72%, and one quarter of the firms invest at least 83% of the time. Subsidy and tax credit policies do not induce a higher R&D participation rate than laissez-faire. The first best policy increases R&D participation by only one percentage point the level achieved under laissez-faire.

Regime	Mean	S.d.	P25	Median	P75	Ratio
Laissez-faire	0.53	0.35	0.13	0.72	0.83	1.00
First best	0.54	0.35	0.14	0.74	0.85	1.02
Subsidies	0.53	0.35	0.13	0.73	0.84	1.00
Tax credit	0.54	0.35	0.13	0.73	0.84	1.02
Finnish tax credit	0.53	0.35	0.13	0.73	0.84	1.00

Notes: The figures are over all simulation rounds and firms.
Ratio = mean of the regime in question divided by the laissez-faire mean.

The differences across the regimes at the extensive margin are somewhat larger than suggested by Table 2: for example, the first best includes (excludes) some projects generating positive (negative) welfare but negative (positive) profits. Such projects are not executed in a laissez-faire economy. Similarly, laissez faire includes some projects with positive profits but negative welfare effects which are not executed in the first-best.

4.3.2 R&D Investments

Table 3 shows that, in contrast to the extensive margin, there are large differences across policy regimes at the intensive margin. The mean R&D investment under laissez-faire, conditional on investing (left panel), is roughly 190 000€ per project over all simulation rounds. The mean investment under the first best policy is more than two times higher. We report the unconditional means in the right panel: these allow us to compare

the R&D investments generated in the economy by different policies taking both the extensive and intensive margins of R&D investments into account. Given that there are only small differences across policies in the probability to invest in R&D, the rankings and ratios in the right panel are close to those in the left panel.

R&D subsidy and tax credit policies induce approximately 40% higher average R&D investments than laissez-faire but fall clearly short of the first best. Table 3 suggests that there is little variation in R&D investment across the three innovation policy regimes. The medians are lower than the means, indicating that the R&D distribution is skewed to the right. Table 3, however, conceals some the differences across the three innovation policy regimes. For example, all firms are supported by public funds in the optimal R&D tax regime. In contrast, in the subsidy regime, only a minority of firms get support, but the supported firms invest on average much more than the other firms because the government can tailor subsidies according to the social returns that projects are expected to generate.

Regime	Investments R&D>0						All investments					
	Mean	S.d.	P25	Median	P75	Ratio	Mean	S.d.	P25	Median	P75	Ratio
Laissez-faire	192 988	641 245	44 114	85 724	176 517	1.00	125 453	606 540	9 302	38 034	101 084	1.00
First best	479 325	1 615 412	112 019	214 187	415 244	2.48	291 749	1 296 669	24 275	97 795	256 168	2.33
Subsidies	273 546	930 529	54 613	117 957	253 242	1.42	180 490	873 616	10 514	53 801	152 984	1.44
Tax credit	278 115	928 760	63 320	123 513	254 498	1.44	182 246	879 938	13 641	55 453	147 155	1.45
Finnish tax credit	274 083	928 849	57 462	119 468	253 116	1.42	180 330	872 631	11 249	53 950	153 068	1.44

Notes: In the column “Investments | R&D>0” the figures are calculated over the simulation rounds where a firm invest in R&D.
 In the column “All investments” the figures are calculated over all simulation rounds and firms.
 Ratio = mean of the regime in question divided by the laissez-faire mean.

4.3.3 Firms' Profits

Counterfactual profit estimates are displayed in Table 4. Profits are naturally higher in the subsidy and tax credit regimes where the government financially compensates part of the firms R&D investments than in the laissez-faire and first best regimes. Profits in the first best regime are lower than in the laissez-faire because firms no longer invest at the profit-maximizing R&D levels.

In general, profit differences across various regimes are much smaller than those in R&D investment because, as suggested by Table 2, almost half of the firms invest in R&D in none of the regimes and are hence unaffected by the policies of the regimes.

Regime	Mean	S.d.	P25	Median	P75	Ratio
Laissez-faire	1 829 289	10 999 334	80 441	429 784	1 280 492	1.00
First best	1 754 989	10 770 461	68 918	392 743	1 202 066	0.96
Subsidies	1 864 117	11 217 445	80 746	434 700	1 305 566	1.02
Tax credit	1 878 900	11 238 477	84 347	444 939	1 321 620	1.03
Finnish tax credit	1 874 684	11 223 011	82 145	441 910	1 320 601	1.02
<i>Notes:</i> The figures are over all simulation rounds and firms. Ratio = mean of the regime in question divided by the laissez-faire mean						

4.3.4 Spillovers (R&D Externalities)

In Table 5 we report the effects of the firm's R&D on the rest of the society. We call these spillovers for brevity. As explained in TTT (2013, 2017), we assume that R&D spillovers are the product of spillovers per euro of R&D times the amount of R&D. As a result the ranking of the regimes in terms of spillovers follow the ranking of regimes in terms of R&D investments. Spillovers are much lower than firm profits in all regimes, ranging from 68 000€ (4% of the profits) under laissez-faire to 176 000€ (10% of the profits) under first best. While the subsidy and tax credit policies increase spillovers almost 50% compared to laissez-faire, they are less than 60% of the spillovers generated by the first best.

Tables 3 and 5 reveal that the subsidy policy and the Finnish tax credit regime combining subsidies and tax credit increase spillovers relatively more than R&D investments whereas the tax credit only - regime increases spillovers only in relation to R&D. The reason for this is that subsidy policies can be used to encourage R&D investments in particular when they create large spillovers whereas tax credits encourage R&D investments irrespective of the level of spillovers they generate.

Regime	Mean	S.d.	P25	Median	P75	Ratio
Laissez-faire	68 389	316 452	5 624	23 120	60 568	1.00
First best	175 908	776 042	14 966	60 840	158 190	2.57
Subsidies	102 236	476 701	6 299	32 807	93 349	1.49
Tax credit	99 379	459 205	8 233	33 707	88 229	1.45
Finnish tax credit	102 038	476 345	6 720	32 941	93 046	1.49
<i>Notes:</i> The figures are over all simulation rounds and firms. Ratio = mean of the regime in question divided by the laissez-faire mean.						

4.3.5 Fiscal Costs

In Table 6 we report direct fiscal costs of the subsidy and tax credit policies, without taking into account the shadow costs of public funds. When we calculate fiscal costs across all simulation draws (i.e., irrespective of whether a firm invests in R&D or applies for subsidies), we find only small differences across the innovation support regimes. The tax credit – only policy is the most expensive since it induces costs in case a firm invests in R&D whereas subsidies induce costs only if a firm invests *and* receives subsidies.

Regime	Mean	S.d.	Mean R&D>0	S.d.
Subsidies	58 256	291 605	85 521	324 260
Tax credit	60 141	290 379	91 778	306 491
Finnish tax credit	58 463	292 754	86 567	324 647

Notes: The figures are calculated over all simulation rounds and firms, without taking into account the shadow cost of public funds.
Mean | R&D>0 is mean of those firms that invests in R&D

The difference between the subsidies only regime and the Finnish R&D tax credit regime that combines tax credits and subsidies is essentially zero. From the outset this is somewhat surprising since both regimes share one innovation policy tool, subsidies, and the other supplements it with another, R&D tax credits. The reason for the finding is that the different regimes affect firms' and the agency's behavior. As reported in Table 7, we find that firms are 14% less likely to apply for subsidies when tax credits are also available. Further, we find that the average subsidy rate conditional on applying stays 0.39 irrespective of whether the tax credits are available or not and finally, that the received subsidy, measured in euros and conditional on receiving a subsidy, rises from 207 000€ without tax credits to 240 000€ if tax credits are available.

Table 7. Subsidy policy parameters			
Regime	Application pr.	Subsidy rate application	Subsidy s>0
Subsidies	0.21	0.39	207 450
Finnish tax credit	0.18	0.39	239 916
<i>Notes:</i> The figures are calculated over all simulation rounds and firms. The second column gives mean application probability. The third column gives mean subsidy rate conditional on applying for one. The fourth column gives mean subsidy conditional on receiving one.			

4.3.6 Welfare

The ultimate measure of an R&D subsidy is its impact on welfare. Our welfare analysis compares counterfactual outcomes to what the Finnish government obtains through the current policy, as measured by our revealed preference approach explained in TTT (2013, 2017). We find (see Table 8) that all regimes are similar in terms of welfare. Although the first best policy substantially increases R&D investments and spillovers from laissez-faire (Tables 3 and 5), it leads to lower profits (Table 4). Since spillovers only constitute a fraction of profits, the welfare improvement in the first best regime com-

pared to laissez-faire is small (2%). This leaves little room for any policy to increase welfare.

Thus, while results in Tables 3-5 show how the R&D subsidy and tax credit policies increase R&D investments, profits, and spillovers, results in Table 8 suggests that these innovation support policies do not improve welfare once the direct fiscal costs of the policies (Table 6) and the shadow cost of public funds are taken into account. For example, compared to a laissez-faire, the Finnish tax credit policy increases firm mean profits by 45 000€, mean spillovers by 34 000€ and creates a mean social cost of 70 000€ (58 000€x1.2), resulting in a mean 9 000€ welfare increase per R&D project. The subsidy policy performs worst, actually slightly lowering welfare from a laissez-faire, due to the application costs that it imposes on firms.

Regime	Mean	S.d.	P25	Median	P75	Ratio
Laissez-faire	1 897 679	11 313 051	86 287	452 573	1 342 183	1.00
First best	1 930 898	11 444 897	89 895	466 206	1 375 898	1.02
Subsidies	1 896 446	11 347 054	85 569	448 246	1 335 025	1.00
Tax credit	1 906 109	11 346 033	87 216	456 121	1 350 427	1.00
Finnish tax credit	1 906 566	11 350 154	86 816	455 407	1 350 845	1.00
<i>Notes:</i> The figures are calculated over all simulation rounds and firms. Ratio = mean of the regime in question divided by the laissez-faire mean.						

4.3.7 Effects of Non-linearities in the Finnish R&D Tax Credit Scheme

A prominent part of the Finnish R&D tax credit regime were the lower and upper thresholds analyzed theoretically in Section 4.1. We also study the quantitative importance of the thresholds. We report the counterfactual results than concern the lower threshold in Table 9. The columns show the various effects at the lower threshold. The first row indicates that probability that a firm is affected by the lower threshold is 6%. The second and third rows show that the threshold leads on to an R&D increase of 7 700€ on average, at a cost of 5 800€ to the taxpayer, respectively. The increase in spill-

overs is quite substantial and, all in all, welfare is improved by almost 3 000€ conditional on the firm's R&D being affected by the threshold.

Table 9. Lower threshold		
Effect	Mean	S.d.
Probability of being affected	0.06	0.046
Change in R&D	7 658	1 761
Fiscal cost	5 827	3 120
Change in profit	4 471	2 093
Change in spillovers	5 488	2 518
Change in welfare	2 967	1 249
The figures are calculated over all simulation rounds and firms. The first row gives the probability that a firm is affected by the lower threshold. The subsequent rows condition on being affected by the lower threshold.		

Turning to the effects at the upper threshold, we find that in 3% of all simulation round - firm observations, a firm's R&D exceeds the upper threshold of 400 000€ of R&D labor expenses. These cases result in the firm getting a pure transfer of 80 000€ (400 000€x0.2) euros with no effect on R&D. To measure the implications for the public finances, we multiply this number by the estimated probability of 0.03 that a firm invests at least 400 000€ into R&D labor. We divide the resulting 2 400€ by 56 463€, the average cost to the government per potential project from Table 6. The resulting 4% is our estimate of what fraction of government costs are pure transfers to R&D intensive firms without any effect on the level of R&D. These transfers are not entirely welfare neutral as they generate the opportunity cost of government funding. Using the corporate tax rate of 0.245 of the years 2013-2014 instead of the 0.2 tax rate in place thereafter would result in a larger cost estimate.

These calculations assume both that the capital-labor ratio of R&D investment is not affected, and that all increase in R&D is true as opposed to the result of reporting non-R&D expenses as R&D expenses for tax purposes. The former is probably at its most tenuous at the lower threshold where the price of R&D labor can be negative. If

firms were able and willing to change the capital-labor ratio, we would underestimate the impact of the lower threshold.

4.3.8 Robustness

We re-estimate our model and recalculate our counterfactual outcomes, first, using only data on subsidies instead of subsidies and subsidized loans, and second, excluding the three largest firms in the estimation sample. We find that our results on R&D participation and welfare comparison of the regimes relative to laissez-faire are unchanged from Tables 2 and 8. The estimated levels of R&D investment and by extension, profits, externalities and welfare, are somewhat lower when using only subsidies, and somewhat higher when excluding the three largest firms by employment. The former effect expected as we make the support regime less generous and thereby less attractive to the firms. The latter effect suggests that the three largest firms do not have particularly large and profitable R&D projects.

There are some caveats to our conclusions. On the one hand, our welfare estimates of the R&D subsidy and tax credit policies are likely to be upward biased: although we take into account the firms' subsidy application costs, we ignore all administrative and accounting costs (those that policies impose on government agencies and those that tax credit policies impose on firms). We also assume a benevolent policymaker. On the other hand, global welfare is likely to be understated because, e.g., a large part of consumer surplus and technological spillovers generated by the Finnish R&D projects is captured abroad but that part should not be included in the agency's objective function. That we ignore firm's international R&D location decisions may also lead us to underestimate the benefits of support policies. Further, our estimates ignore the possible dynamic effects of government support. In particular, our estimates suggest that R&D fixed costs are lower for firms that engaged in R&D in the previous year.

Such dynamic effects may increase the probability of non-R&D-performing firms to start R&D once support is available.

Regarding the R&D tax credit scheme, we ignore the firms' incentive to change the labor-capital composition of their R&D investments in favor of labor. This omission means that we may be understating the effects of the R&D tax credit. We also ignore the possibility that firms could engage in cost-padding and -shifting activities, inflating their R&D wage bills. This simplification means that our estimate of the fiscal effect of the scheme is underestimated.

We also assume that all firms are aware of the tax credit scheme. This assumption, together with our assumptions of no administrative costs and of the scheme staying in place as planned, leads to an overestimate of the popularity of the tax credit scheme among R&D performing firms.

5. Conclusions and Policy Implications

This report consists of three distinct but interrelated parts. The first part is a discussion of the economics of innovation policy where special emphasis was given to the viewpoint of a small open economy. The second part consists of a qualitative analysis of various innovation policies used in Finland. The third part reports the results of a quantitative counterfactual welfare analysis of the Finnish R&D subsidy policy the Finnish R&D tax credit policy used in Finland in 2013-2014. We call these policies “the Finnish R&D subsidy policy” and “the Finnish tax credit policy”, respectively, but the reader should keep in mind that our welfare evaluation is a prediction of what would happen if the policies stayed in place.

Our qualitative analysis provides the following findings:

- The available evidence from empirical and theoretical research suggests that bottom-up policies have a higher chance to succeed on average than mission oriented

top-down policies. The conclusion largely follows from the nature of innovative activities: they are hard to pin down and predict and often surprising in their consequences. It is likely that the public sector is at an informational disadvantage. This disadvantage decreases the probability that even a benevolent policy maker could make correct decisions at using a top-down approach. Top-down policies are also particularly vulnerable to lobbying. We think that the Finnish innovation policy should more explicitly be based on a bottom-up approach, rather than vice versa, with the aim of allowing agglomeration of resources into those sectors and regions that show signs of success.

- Any individual innovation policy should be placed into a broader framework that consists not only of other innovation policies, but also of the policies for innovation (“indirect innovation policies”). It may well be that the best governmental innovation policies are the least headline-grabbing ones, focusing on building the right infrastructure for better informed agents with stronger incentives, be they academic researchers or corporate inventors.
- The Finnish innovation policy-making process should take into account the political economy considerations. For example, if benefits of an IPR policy change are concentrated to certain interest groups, but its costs are spread out to consumers, consumers’ viewpoints should be paid particular attention.
- There is a need to evaluate the Finnish IPR policies and government equity investment policies, paying attention to the small open economy considerations.

In our counterfactual welfare analysis we study the current regime of subsidies only, the Finnish regime of 2013-2014 where both subsidies and R&D tax credits were available, and the R&D tax credit only regime without subsidies (and which has been never used in Finland). This analysis yields the following findings:

- The subsidy and tax credit policies increase R&D investments and spillovers substantially. However, once the shadow costs of public funds, and firms' subsidy application costs are taken into account, they hardly increase welfare.
- The differences between the three innovation policy regimes are minor.
- We predict that the lower threshold in the Finnish R&D tax credit scheme of 2013-2014 would have resulted in a major shift in R&D investments of firms engaged in small R&D projects. These shifts would have been costly in terms of government funding in relation to the increase in R&D that the support induced, but our estimates suggest they would have been marginally welfare improving.
- The upper threshold in the Finnish R&D tax credit scheme capping the R&D tax credit would have lead 4% of government expenses towards increasing R&D of being transfers to firms without any effect on their R&D.
- While we do not investigate the effects of changes in Tekes's budget, our findings suggest that subsidies granted by Tekes affect the level of R&D investments substantially but do not affect welfare. This finding suggests that analysing the effect of Tekes's budget changes on the allocation of subsidies would be essential.
- The mission of Tekes should be focused on increasing societal welfare trough supporting R&D projects that generate positive externalities. Investments in increasing Tekes's ability to identify the spillover rate of different projects could have a high social return. More research is needed to shed light on the question of whether Tekes manages to allocate funding to projects with high spillover rates.

Our estimations suggest that optimal innovation policies can at best increase welfare only by 2% compared to a laissez-faire outcome. We view this as a lower bound estimate. For example, we find that the socially optimal level of R&D should be 100% higher than in a laissez-faire. This estimate for the socially optimal level of the R&D is in the same range as ones by Jones and Williams (1998) and Bloom, Schankerman, and

Van Reenen (2013). If we assume that R&D generates larger externalities than what our estimations suggest, the scope for welfare improving innovation policies would be larger. Similarly, while we find that subsidy and tax credit policies hardly affect welfare, we find that they increase R&D investments 40% from a laissez-faire. For many, such an effect on R&D investments would indicate the usefulness of these policies.

Finally, both our qualitative and quantitative analyses suggest that the rationales for prioritization of exporters and SMEs in innovation-policy making (which is what for example Tekes is doing based on its mission and our results in TTT 2013 and 2017) may be more complex than what is commonly thought. While trade unambiguously enhances innovation and productivity, a large part of the wedge between social and private returns to innovation disappear from the point of view of a national policy maker in the case of exporters. As to SMEs, while they may create disproportionately more important innovations than larger firms (Akcigit and Kerr 2016), they may matter less for productivity growth (Garcia-Macia, Hsieh, and Klenow 2016) and they appear to create smaller spillovers (Bloom, Schankerman, and Van Reenen 2013). It is also the case that financial market imperfections (from which SMEs presumably suffer more than large firms) cannot be unambiguously used as a rationale for larger support (as we show in TTT 2013b and 2017). We do not suggest that the emphasis on exporters and SMEs is necessarily misplaced but spelling out the rationales behind the emphasis would be useful.

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