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A comparison of Finland and Sweden, 1970-2013

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Impact of innovation policy on firm innovation – A comparison of Finland and Sweden, 1970-2013

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Abstract

To what extent have public policies contributed to the innovation performance of Finland and Sweden in the period 1970-2013? This paper aims to assess the share of innovations stimulated by the public sector, specifically because of receiving public funding or being the result of research collaboration with public institutions. We combine survey and LBIO results on these variables, to overcome reporting biases found in the two methods.

The main data comes from the new UDIT dataset, which gathers the most significant innovations of both countries for the period, in total about 4,100 Swedish and 2,600 Finnish innovations. It has been constructed following the LBIO method (Literature Based Innovation Output), which obtains information on relevant commercialized innovations from general technology journals as well as industry specific trade journals.

Our results indicate that Finland had a substantially larger public involvement in these innovations than Sweden. This is specially true in the years between 1990 and 2000, when we see a drop in the relative role of the Swedish public sector in innovation output, while the Finnish trends are constant or slightly increasing over the period. However, in both countries public policies lie behind a significant share of the innovations (30-50% in Finland, 15-35% in Sweden), and in the Swedish case we can further assess that the publicly stimulated innovations were more often found among the most significant new products (written about in several articles).

JEL Codes: I28, N70, O38, O57
Keywords: public policy, innovation, LBIO method

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Introduction

Innovation-led growth is high on the public agenda today. To achieve sustained (and sustainable) improvements in societal well-being, new and smart solutions to problems should be put into practice. This is relevant for countries at all stages of economic development, and has definitely also been important in the past – significantly, economic historians have sometimes depicted the evolution of the world economy in the last 250 years as a succession of "technological revolutions" (Perez, 2003; Mokyr, 2010).

It is important to understand what can make societies successful in attaining innovation-led growth. Aspects such as human capital accumulation or a stable environment for investment would undoubtedly come to mind. The public sector is arguably present in many of the intervening factors, although the importance of its direct contribution in the sense of funding innovation development is the subject of some debate.

Evaluation of public policy impact on innovation has received increased attention in recent times, but has sometimes proven very elusive – not least because it is problematic to establish what the outcome variable should be. A significant part of the literature has focused on whether public funds stimulate or crowd out private investment on R&D (Wallsten, 2000; Lerner, 2000; Görg and Strobl, 2007; González and Pazó, 2008).

The focus of this paper is on the effects of public stimulation on innovation *output*: actual innovations, i.e. new products and processes introduced on the market. Our context are the economies of Finland and Sweden in the period 1970 to 2013. These two countries are among the top innovative countries according to comparative indicators of innovative activity such as R&D expenditure, and they also score high in the European Innovation scoreboard.[6] A novelty of this study is to address the direct public impact on innovations, through data on significant innovations obtained from the LBIO method in a comparable way. With "significant" innovations we mean those that have been perceived as important enough by field experts to write about them in trade journals.[7]

The main question of the paper is: what has been the role of policy for innovation output in Finland and Sweden? As can be seen in figure 1, in Finland the total number of significant innovations followed an S-shaped curve: it started at a lower level in the 1970s, then rapidly increased during the late 1980s and 1990s, to levels similar to those in Sweden, but finally

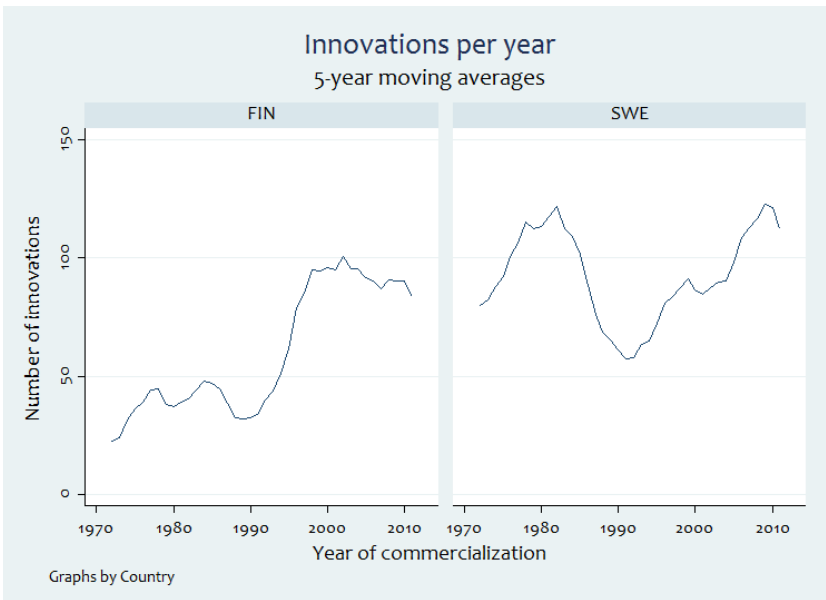
[6] See: https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards. Accessed 11/4/2017.

[7] The Literature Based Innovation Output method consists in gathering information about innovations that are written about in trade journals. It will be further explained in section . We claim that our data is a reasonable representation of the most important innovations introduced in these countries over the period considered. Throughout the paper, when writing "innovations" we refer to these sample of "significant innovations".

stagnated since 2000.[8] Sweden's evolution looks more N-shaped, with a sharp decline in the 1980s and a trough in the years surrounding 1990, followed by a surge ever since. Given that Finland has a smaller population and economy than Sweden, its performance since 1990 is even more impressive than the absolute innovation counts indicate.

Did public innovation policy play a role in these innovation patterns?

Figure 1: Annual number of significant innovations in Finland and Sweden, 1970-2013



Source: UDIT database (see section 4).

Our main results point towards a larger public involvement in significant innovations in Finland than in Sweden, which holds across the whole period considered, but specially in the years between 1990 and 2000. In Finland the trends in publicly stimulated innovations are slightly increasing, while in Sweden they display a cyclical pattern, which corresponds to the ups and downs of the total innovation counts shown in figure 1. In the Swedish case, we can also say that the public sector was more often found behind the most significant innovations (completely new, and written about in several journals).

The rest of the text is organized as follows. The literature section deals with previous work in the area of innovation policy, with a special focus on Finland and Sweden. Section describes the evolution of the institutions providing public support for innovation in both countries. Section presents the database used as a basic source for this study, and defines

[8] This convergence in innovation output took place at the same time as Finland's GDP per capita reached that of its previously wealthier neighbour. The slight divergence at the end is also seen in both indicators.

the variables of interest. Section 5 proceeds to the method challenges that have been encountered, and how they have been dealt with. Our results are shown in section 6 and, finally, section 7 concludes.

Previous literature

Governments in developed countries have a long-term history of supporting innovation and private R&D. The history of innovation policy goes back to at least the years directly after The Second World War, when, under the label of science policy, investments in science and research were seen as means to unleash progress, security and prosperity (Fagerberg, 2016; Borrás, 2003). In the 1970s the focus moved towards technology policy and the industrial application of knowledge through e.g. technology transfer, science parks and R&D collaboration, and in the 1990s the concept of innovation was strongly brought up in particular through the system of innovation approach, hence opening the 'era' of innovation policy (Sharif, 2006). More recently the significance of innovation policy has increased in both advanced economies and developing countries, due to slow economic growth and the need to respond to global grand challenges where innovation is seen as one source of response. At the same time, there has been a growing need to show evidence on the impacts of innovation policy and on the societal and economic benefits of financial investments on R&D.

The main justification for public stimulation of private R&D is based on the idea of market failure (Arrow, 1962). Companies underinvest in research and development activities due to the inherent high risks and uncertainty of the results and benefits. This is related to knowledge being a public good, which makes it difficult for companies who have invested in knowledge production to exploit it exclusively (Fagerberg, 2016). Moreover, companies' R&D is easily geared towards short-term goals and hence neglecting strategic R&D objectives and activities that are important from the perspective of long-term competitiveness. From society's point of view, private underinvestment in R&D represents a problem because the societal benefits are expected to be larger than the costs.

More recently, the literature on systems of innovation has pointed to an additional rationale for government R&D funding and intervention apart from pure market failure: system failures (see e.g. Smith, 2000; Klein Woolthuis et al., 2005). By emphasising the interactive nature of innovation and its institutional embeddedness, the innovation system approach has broadened the perspective on the innovation process and identified a number of areas of systemic imperfections such as infrastructural failures, institutional failures, interaction failure, network failure and capabilities' failure (Klein Woolthuis et al., 2005). The role of the government, then, would be to try to mitigate system failures not only through funding, but rather through other policy instruments such as cooperation, networking, regulation and creation of incentives.

As with all policy domains, innovation policy relies on a number of different measures and instruments. These are normally divided into supply-side measures (promoting the supply-side, i.e. providing additional inputs to firms and other actors undertaking R&D and innovation) and demand-side measures (which aim at stimulating innovations by accelerating their demand; Edler and Georghiou, 2007; Aschoff and Sofka, 2009).[9] Supply-side measures include financial instruments, in particular funding for public sector research to produce scientific knowledge and R&D subsidies to firms, but also R&D tax credits, support for training and mobility, and services such as information and networking facilities. Demand-side measures comprise public procurement of innovation, regulation, support for private demand of innovations as well as systemic policies. Policy-making instruments are usually designed and combined into various types of policy-mixes aiming to address certain problems in the innovation system (Borrás and Edquist, 2013). Hence also the policy-mixes in different countries tend to have different emphases e.g. between direct subsidies and tax credits (e.g. Hewitt-Dundas and Roper, 2010).

What we are particularly interested on here, is the impact of these policies and instruments on innovation output. There is a huge literature on the effects of innovation policy measures, which it is outside of the scope of this article to review. In contrast, we point to some of the main lines of research and in particular to those that are of key relevance from the perspective of the analysis that is presented in the following sections. Hence we focus on 1) R&D subsidies, and 2) public research. Demand measures such as regulation and procurement, or other public actions such as the provision of education, are not directly addressed in the paper.[10]

R&D subsidies

As financial instruments are the main backbone of innovation policy, there is a vast literature of econometric studies examining the impact of especially direct R&D subsidies (for an overview, see e.g. David et al., 2000), but also of R&D tax credit systems (e.g. Hall and Van Reenen, 2000). A large share of this literature has focused on the question of whether there is additionality, i.e. whether public support increases private R&D investments, or if it crowds them out (Takalo et al., 2013). The evidence for addionality of R&D subsidies is mixed. Some studies suggest additionality (e.g. Czarnitzki & Lopes-Bento, 2012; Beck et al., 2014). This

[9] In practice, however, the distinction between supply and demand-side instruments is not so clear-cut and there is, for instance, a debate whether pre-commercial procurement actually represents a demand or supply-side instrument (Edquist & Zabala, 2015).

[10] There are fewer studies analysing demand side instruments. Some useful references for public procurement, which generally find some positive effects, are Aschhoff and Sofka (2009), Pelkonen and Valovirta (2014), and Czarnitzki et al. (2016). In terms of regulation, the evidence is not unambiguous and provides a rather heterogenous picture; see e.g. Blind (2012) or Aschoff and Sofka (2009). However, the literature tends to point to long run positive impacts of e.g. especially environmental regulations on innovation (González, 2009; Blind, 2012).

means that public investment rather seems to attract additional private funding, than to crowd out private investments. Yet, there are also more critical studies suggesting no additionality or even substitution effects (e.g. Marino et al., 2016), the latter meaning that there would be no gains from public investments, and studies showing different types of effects for different types of firms (e.g. Lee, 2011) or for different types of subsidy programmes (Clausen, 2009). For tax credits, there are both studies showing positive effects (e.g. Hall and Van Reenen, 2000) and studies with mixed results in terms of impacts (e.g. Lokshin and Mohsen, 2014).

The vast majority of the literature examines additionality by looking at the impacts from public funding on private R&D expenditures (and R&D employment) and not on the actual output of the activity, i.e. innovation. Prior studies looking at the impact of R&D subsidies on innovation output are very scarce, nearly non-existing. This is where our study aims to fill a knowledge gap. Yet, there are a few prior studies such as Beck et al. (2014) who examined the effects of public R&D subsidies on firm innovation and distinguishing between the degree of innovation novelty. Interestingly, they found that firms benefit from publicly funded R&D investments, especially in terms of increased innovation performance with radical products. So public funding was linked to higher quality of the innovations. Czarnitzki et al. (2007) studied the impact of public funding on patenting activies (and R&D) in Finland and in Germany and found a positive impact especially in Finland. A third relevant study is Guo et al. (2016), who studied the impact of a government R&D programme on firm innovation in Japan. They measured firm innovation outputs by number of patents, sales from new products and exports and found that firms that received funding from the programme generated “significantly more innovation outputs” compared to a control group of firms.

Academic Research

On the supply-side, public support for the production of scientific knowledge at universities and public research institutions is the largest instrument in terms of volume in most countries. Although public science does not provide direct support for firms’ innovative activities, its significance for technological change and private sector innovation has been acknowledged (e.g. Pavitt, 1991). The contribution of basic research to industrial innovation takes place through university-industry interaction and collaboration: collaborative research, contract research, licensing, personnel mobility and training. The impacts of these kinds collaborations has been object of a large number of empircal studies the majority of which shows that firms’ innovative activities benefit from collaboration (e.g. Mansfield and Lee, 1996; Lööf and Brorström, 2008; Huang and Yu, 2011; Wirsich et al., 2016).

For instance, it has been estimated that over 10 per cent of new products and processes in a number of industries would not have materialized in the absence of academic research (Mansfield, 1998; see also e.g. Beise and Stahl, 1999). There are also evidence that these impacts may be stronger in certain sectors (such as manufacturing in contrast to services; Lööf and Brorström, 2008) and for certain types of innovations (product in contrast to process innovations; Beise et al., 1999; and radical innovations in contrast to more incremental ones; Belberbos et al., 2004).

In general, while the literature on the impacts of public sector support for firm innovation is relatively vast, there are some deficiencies to which our paper tries to contribute. First, there are practically no studies where the impact of public innovation policy measures is studied in terms of the actual outcomes, i.e. innovations in a country. Usually impact indicators are indirect measures such as patents, sales of new products, R&D expenditure, etc. A LBIO-based approach hence provides a new perspective to the study of innovation policy impacts.

Another gap in the literature is that very few studies analyse several types of policy interventions at the same time and try to provide a comperative perspective on the effects of various instruments. In this article we examine the impacts of two different types of instruments: public &D funding and public research, hence providing a broader picture and allowing for some comparison.

The public innovation support landscape in Finland and Sweden since the 1970s

The public R&D funding and research landscape are quite different in Finland and Sweden today. The R&D funding scene in Finland is dominated by a few large actors, while Sweden has a large and complicated web of actors, partly overlapping each other's responsibility fields. When it comes to public research, the Swedish model has centred on universities with a modest role played by research institutes, whereas in Finland both types of institutions have co-existed and complemented each other.

In Sweden, the evolution of the public R&D funding structures has involved a number of changes over the years. Major changes in the landscape of government R&D-funding bodies occurred in 1968, 1991, 1997 and 2001. In 1968 the Swedish Board for Technical Development (STU) was established, through a merger of the Engineering Research Council (TFR), the Iron Ore Fund and three smaller organizations.[11] In 1991 STU was temporarily merged with the National Energy Administration and the National Industrial Board to form the National Board for Industrial and Technical Development (NUTEK). In 1997 the energy-related activities were split off from NUTEK to form what is basically today's Swedish Energy Agency and relocated to Eskilstuna. In 2001 the technology division of the remaining NUTEK, roughly corresponding to the previous STU, was merged with the Transport and

[11] The history of STU, including its establishment, is dealt with in Weinberger (1997).

Communications Research Board and part of the Council for Working Life Research (RALF) to form today's VINNOVA (Swedish National Government Agency for Innovation Systems). In the same year, 2001, several research councils were consolidated into the three research councils of today (VR, Formas and Forte). The semi-public research foundations that were merged in 2001, had been established in the mid 1990's using part of the capital in the so called Wage Earner's funds.[12] The fundamental restructuring of the R&D-funding system in 2001, in addition to achieving some consolidation of the complex funding landscape, at least partly settled a long-time tension in the Swedish research policy between funding of curiosity-driven research on the one hand and funding of research and innovation motivated by the needs of industry and society at large on the other.[13]

A basic design for the public funding of industrial R&D was created in Finland in the late 1960s and 1970s. The government budget in 1967 for the first time included competitive funds, which the Ministry of Trade and Industry was entitled to use to support R&D in companies. In the same year SITRA, the Finnish National Fund for Research and Development, introduced a new R&D grant and loan scheme financed from returns of the fund.[14] A few years later, in 1971, two business support organisations were established: the Regional Development Fund of Finland Ltd, with mission comparable to Norrlandsfonden in Sweden, and the Foundation for Finnish Inventions to support and promote private inventors (Murto et al., 2007; Carlson, 1987).[15] After its establishment in 1983, Tekes took over the allocation and management of competitive R&D funding, formerly administered by the Ministry of Trade and Industry (Lemola, 2003).[16] The structures created for channelling and administering government funding for company R&D and innovation activities and public research stayed largely intact up until the early 2000s. In recent years, however, the public business support structures have become a target of revision and restructuring.

Public funding of company R&D

In the case of Finland, Tekes has since its establishment in 1983 been the focal agency for allocation of government funding to company R&D and collaborative research bridging companies and research organisations. Tekes combines most of the R&D-funding roles of VINNOVA, the Energy Agency and the National Space Board in Sweden. Compared to its Swedish counterparts, Tekes has put relatively more emphasis on direct competitive funding of company R&D through grants and loans it provides. Tekes' budget grew briskly at the end of the 1990s, decreased slightly during the first years of 2000s but was growing again in the

[12] *Löntagarfonderna* (wage earner's funds) were installed to increase the trade unions influence in firms through partial ownership. They were abolished and most of the money went into research foundations in 1992.
[13] Some central issues in Swedish research and innovation policy are discussed in OECD (2016).
[14] *Stiftelsen Riksbankens Jubileumsfond* founded a few years earlier in Sweden was used as a model for SITRA.
[15] Kehitysaluerahasto Oy/Kera Oy, transformed into Finnvera Plc in 1999.
[16] The Swedish *Styrelsen för Teknisk Utveckling* (STU) was used as a blueprint for the new funding agency.

period of 2003-2010. However, the situation has changed in the aftermath of the financial crisis. The annual government R&D funds have been cut since 2010 and Tekes budget has been significantly scaled down in the new environment. Cuts and reshuffling of the public funds have caused the agency to reconsider the focus and extent of its activities. In the new situation the agency has refocused its activities and targets particularly innovative, growth-oriented companies looking for international markets.

More generally, the recent changes in the allocation of public R&D funding have been shifting the focus gradually towards basic research and the so called strategic research on societally important themes funded via the Academy of Finland and a new body (Strategic Research Council) under the Academy administration.[17] The current development is in contrast to decisions made during the severe economic crisis in the early 1990s when the government of Finland deciced to continue to increase public investment in R&D and not least through Tekes.

In Sweden, government funding of R&D-activities in which companies participate is primarily channeled through VINNOVA, the Swedish Energy Agency, the Swedish National Space Board (via the European Space Agency ESA) and through defense authorities as part of procurement of defense equipment. Projects funded by VINNOVA or the Energy Agency are often carried out in collaboration with universities or research institutes, in which case companies will usually cover all or the main part of their own costs (Svensson, 2014; VINNOVA, 2015).

Government funding of R&D of relevance for the business sector has generally been given less priority and seen much less of a consistent pattern of growth in Sweden than in Finland. After some growth during the 1970s and 1980s in Sweden, such funding stagnated during the 1990s and NUTEK's budget for funding of R&D was even cut back drastically around the mid 1990s as a result of a failed attempt by the then minister of education, Carl Tham, to dissolve the semi-governmental research foundations created by the preceding centre-right government. After a decade long period of relative stagnation before and after the turn of the millennium (especially when seen in relation to increasing "unit costs" of research), government R&D-funding in Sweden has grown strongly during the last decade in monetary terms. The increase has mainly gone to universities through one channel or another. In terms of government funding of industrially oriented R&D, various partnership programs have received increased funding, most recently through the new Strategic Innovation Areas initiative launched in 2012, which is managed jointly by VINNOVA, the Energy Agency and Formas.

[17] Regarding our analysis, the recent cuts and revisions of focus of public R&D funding in Finland do not necessarily yet show up in the data covering years 1970-2013.

Industry close public research

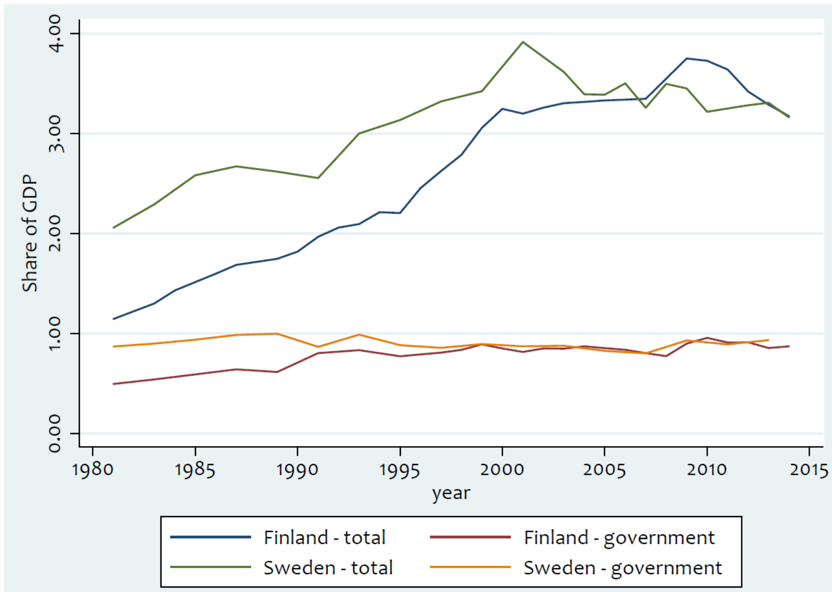
Organisation of public research has followed different paths in Finland and Sweden. In international comparison, industrial research institutes make up a small part of the Swedish research landscape. This has its historical roots in the so called Malm Commission which during the 2nd World War concluded that it was better to increase research funding at the existing universities than to build up new research institutes. In Finland an opposite route was chosen, and the government research institutes alongside of universities have been an integral part of the research system. The largest of the research institutes, VTT - Technical Research Centre of Finland, has played a prominent role in implementation and advancement of industry oriented research and technological R&D since its founding 1942 (Arnold et al., 2007).

The closest counterpart to the government research institutes in Finland and particularly to VTT in the Sweden are the industrial research institutes. After a long period of declining government funding these institutes have in recent years received more attention and an increase in basic funding although this is still quite limited. Furthermore, there has been a gradual consolidation of the institutes into four institute groups, three of which have recently merged into one now fairly large institute (RISE Research Institutes of Sweden AB). The Finnish research institute sector has also went through a thorough restructruring during the 2000s. The institutes have been merged into larger units while decreasing their annual share of direct budget funding for R&D notably. VTT’s incorporation from the beginning of 2015 was part of the changes implemented.

Trends in funding

Both in Finland and Sweden, the ratio of R&D expenditures to GDP (in short, R&D intensity) has increased markedly since the beginning of the 1980s. During the period Sweden has continued to be among the OECD countries which in relative terms invest most into research and development. In Finland, R&D expenditures were below the average OECD level until the early 1990s, but since early 2000s have been close to the level of Sweden. After the financial crisis the relative share has however been in decline in Finland as private and public investments in R&D have decreased. In comparison, in Sweden the R&D intensity has hovered in the range of 3.2-3.5 percent of GDP since 2008. As we can see from figure 2, it is mostly the growth of private sector investments which has driven the increase of R&D expenditures; the relative share of government funds has decreased from around 43 to 30 percent in both countries during these three decades. Notwithstanding this, the figure shows that a significant increase of public funding relative to GDP comes through in the 1980s and 1990s in Finland.[18]

Figure 2: Gross Expenditure in Research & Development in both countries, as a percentage of GDP

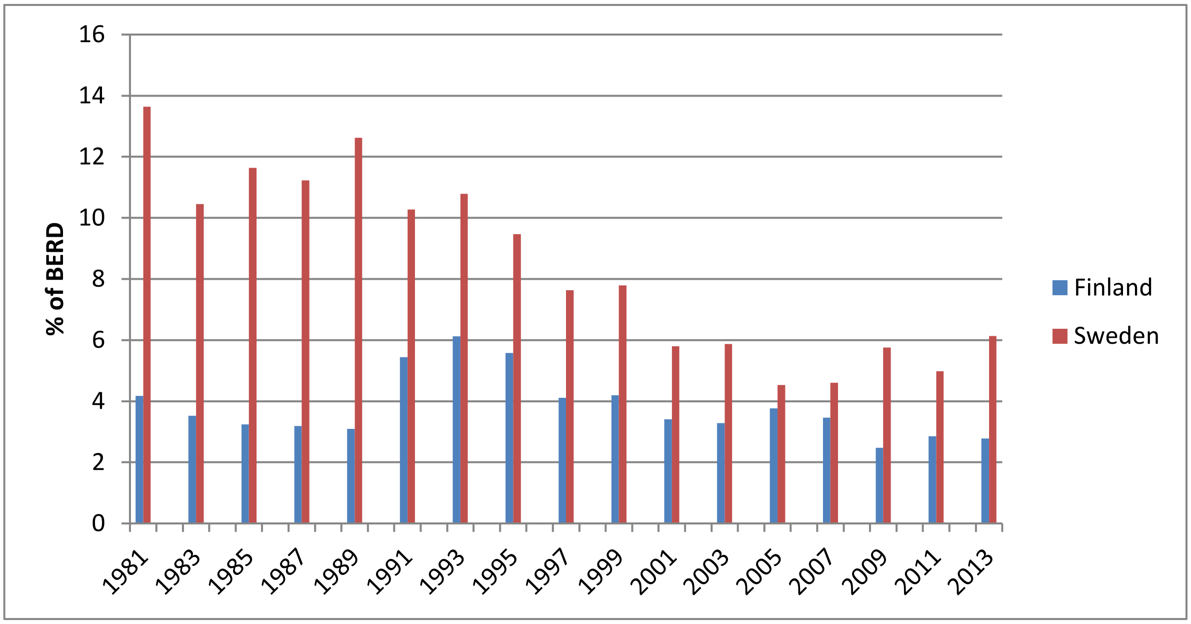


Source: OECD.

What do the statistics tell us about the evolution in public funding of business R&D in the same period? As Figure 3 reveals, the level of government funded intramural business R&D was significantly higher, more than threefold, in Sweden during the 1980s. Since then the difference between the countries decreased notably until 2005, when the share of publicly funded BERD (Business and enterprise Expenditures on R&D) was 3.8 percent in Finland and 4.5 percent in Sweden respectively. The gap started to increase again in the years following the financial crisis, and was more than twofold in 2009 and 2013. The Swedish data show a clear decline in share of public funding of business sector R&D after the 1980s. In Finland the share of government funded private R&D fluctuates in a range of 2.5 to 4.2 percent during the 1980s and the 2000s whereas in the early 1990s for the short period the share is between 5 and 6 percent – which may at least partly relate to the decline of GDP three consecutive years 1991-1993.

[18] R&D expenditure, while usually taken as an indicator of innovativeness, is a broad aggregate of input. Its distribution on research and development, respectively, is hidden in the figure. When comparing with the innovation counts, we should also take into account that not all spending on R&D is directed towards specific projects, but some might be general infrastructure, for example.

Figure 3: Share of government funding of Business and enterprise Expenditures on R&D in Finland and Sweden, 1981-2013



Source: OECD Research and Development Statistics 2017.

Data

The main data source for this paper is the result of a collaborative project between researchers of Finland (VTT, Technical Research Centre of Finland) and Sweden (Lund University). Its origins lie in the thesis by Saarinen (2005), and it has come to build up a joint database with the main innovations in both countries, for 1970-2013, with a common basic methodology and variable definitions.

SFINNO, SWINNO, and UDIT

Our innovation data has been gathered using the LBIO method, which consists of identifying innovations from trade journals. The method has been used in several previous studies (e.g. Audretsch, 1991; Kleinknecht and Bain, 1993), and was followed to construct similar databases for Finland (Palmberg et al., 2000; Saarinen, 2005) and Sweden (Sjöö et al., 2014). This method is intended to capture important or significant innovations, and not all (minor) innovations in an economy. To do this, we follow the criterion of journal editors in writing about specific innovations and not others.[19]

[19] Throughout the paper, when we talk about innovations in our database, they should always be understood as 'significant innovations' in this sense. We are unable to capture all the innovations developed in an economy

The UDIT dataset is a product of the research project "Understanding Diverging Innovation Trends in Finland and Sweden", that has aimed to analyse the innovation dynamics and outcomes comparatively in the two countries.[20] Consequently, the Finnish SFINNO and the Swedish SWINNO datasets were merged for this into the UDIT dataset. One important feature of the UDIT dataset is that it only contains innovations which were the focus of at least one edited article or an overview article of innovations. Innovations only identified through product announcements in the scanned journals were excluded, since they can be considered to be mere advertisements by companies and not actively selected by journal editors. The combined dataset contains about 4100 Swedish innovations and 2600 Finnish innovations. These are product innovations with which we capture basically the manufacturing sector (i.e., we do not have services without a product component). For each innovation there are up to 31 variables available, with 13 of them being fully comparable across the countries.

One complication for the comparability of variables is that two different methods have been used in Finland to obtain information over time, and this affects specifically the policy-related data. All the Swedish variables, and the Finnish up until 1985, were solely based on extracting that information from the articles. However, since 1985, most of the Finnish variables for the innovations that had first been identified in the journals were collected from surveys sent out to the innovating firms.[21] See table 1.

Table 1: Data collection methods in the UDIT database

	1970-84	1985-2013
Finland	LBIO	LBIO and Survey
Sweden	LBIO	

Source: UDIT project.

This circumstance entails comparability problems: for the variables affected, we cannot directly compare the Finnish data before and after 1985, nor the Finnish with the Swedish trends after 1985. We have turned this challenge into an opportunity to assess the different biases inherent to both methods of data collection: an expected downward bias in LBIO data (not all journalists will ask or write about public stimulation of the innovation), and an expected upward bias in survey results (since it is more likely that firms that got some public support will feel obliged to answer the survey – especially if it is stated that a public funding

for any given period. The SWINNO, SFINNO, and UDIT databases constitute a reasonable approximation to the most significant ones.

20 Funded by Tekes and VINNOVA, the central agencies for innovation development in the two countries.

21 The first survey was sent out in 1999 and covered the years 1985-98. After that, they have been done at more or less regular intervals of 2-3 years.

agency is supporting the investigation). Therefore, we complement the Swedish LBIO data with a survey for 2009-2013 sent out to the innovating firms, and re-read the articles about Finnish innovations, taking out the information about public stimulation from them. Because of time constraints, this additional gathering of data has been restricted to ICT related innovations (roughly 40 percent of the total). The exercise enables us to obtain adjustment factors for the entire innovation sample, based on some plausible assumptions, so that we can estimate how many of the 6,700 innovations were stimulated by public policy in one way or another.

Policy relevant variables

The UDIT database contains several variables, or groups of variables, with information about the role of public policies for innovations: information was collected on collaboration in the development of innovations, involvement of technological programs, public funding, and the potential role of the public sector in the origin (motivation) of the innovation.

These original variables have been reorganized to arrive at four different kinds of public involvement in the innovation, which we refer to as public stimulation variables: public funding, public research (collaboration in research), public regulation, and public procurement. A general "Public stimulation" variable signals innovations where at least one of these aspects was found, and "Public demand" joins the regulation and procurement instruments together. See table 2.

Table 2: Public stimulation variables used in this study

VARIABLE NAME	DESCRIPTION
Public funding	= 1 if the firm received funding from some public body for the development of the innovation
Public research	=1 if the innovation was developed in collaboration with public universities or public research centres, and/or the innovation was originated within a public research program or a public technology program was involved
Public regulation	=1 if public regulation was checked as an origin for the innovation
Public procurement	=1 if public procurement was checked as an origin for the innovation
Public stimulation	=1 if any of Public funding, Public research, Public regulation, or Public procurement =1
Public demand	= 1 if Public regulation or Public procurement =1

Source: UDIT project.

Table 3 shows some initial statistics for the public stimulation variables. A first approach could be to treat the survey results as if they were equivalent to the LBIO data: a value 1 indicates known public involvement in an innovation, with non-responses treated as a 'no' answer. The results of doing this can be seen in the first three rows of the table. The role of the public sector in innovation activity seems to have been much more significant in Finland than in Sweden during the period considered: innovations with some public stimulation are 24 percent in Finland, in contrast to 13 percent in Sweden. The difference is higher if we focus on each of the policy components. But, as argued above, part of it is in all likelihood due to the biases in the survey versus LBIO methods for gathering information.

Table 3: Basic statistics of public stimulation variables

	Total	Public Stimulation		Public Funding	
	Count	Count	Percent	Count	Percent
Finland	2 617	623	23.8%	430	16.4%
Sweden	4 083	535	13.1%	254	6.2%
Total	6 700	1 158	17.3%	684	10.2%
Finland 1970-1984	539	123	22.8%	65	12.1%
Finland 1985-2013	2 078	500	24.1%	365	17.6%
Finland 1985-2013, Response	534	500	93.6%	365	68.4%

	Public Research		Public Regulation		Public Procurement	
	Count	Percent	Count	Percent	Count	Percent
Finland	479	18.3%	315	12.0%	132	5.0%
Sweden	270	6.6%	52	1.3%	22	0.5%
Total	749	11.2%	367	5.5%	154	2.3%
Finland 1970-1984	63	11.7%	33	6.1%	8	1.5%
Finland 1985-2013	416	20.0%	282	13.6%	124	6.0%
Finland 1985-2013, Response	416	77.9%	282	52.8%	124	23.2%

Source: UDIT database.

Note: in the first sub-part of the table, no data in Finland 1985-2013 has been considered as a 'no'. In the second sub-part, the data for Finland is divided according to the method used: the first row depicts results of the LBIO method, while the second one corresponds to the survey. The last row shows the values obtained when limiting the sample to the survey respondents.

For Finland the survey period (post 1985) displays higher values for all the variables, with increases of between 4 and 9 percentage points. The difference is specially high in the apparent role of regulation and procurement. Restricting the sample to survey respondents (last row of the table), we can see that an overwhelming majority of these innovations received public support of some sort: 70-80 percent benefited from public funding or research collaboration with the public sector, while as many as 94 percent had some sort of public stimulation in their development! These high numbers are most likely in part due to overestimation, since some self-selection of respondents that got public support can be expected.

We conclude from this brief exploration that the survey data are not comparable to the LBIO data for the variables related to public stimulation. In the next section, we go through these problems in detail and propose a way to adjust the LBIO results upward, and the survey results downward.

Estimating adjustment factors

As was introduced in section , our data combine two collection methods, since the Finnish public stimulation variables originate from surveys for the post-1985 period. How can we compare the Finnish trends across time, and both countries with each other after 1985? Some adjustments need to be made to ensure comparability over time and between the two countries.

Articles about innovations will likely only mention public funding (for example) if it has been of a high significance for the firm and the new product's development. This means that the values we obtain for these public stimulation variables will always be a lower bound. For example, and going back to the numbers in table 3, 6 percent of the Swedish innovations in 1970-2013 had *known* public funding – for the other 94 percent, we have no information. Obviously, this does not necessarily mean that they did not receive any public funding. We need adjustment factors to correct the percentages upward.

With respect to survey-based data, careful thought has to be given to the selection mechanism of respondents (the average response rate of the Finnish surveys lies at 30 percent, but it has varied a lot over time).[22] Our hypothesis is that firms who received public support in the form of funding would be more willing to respond to the survey, given that it is a public institution who sends it. This would imply that the survey results would be an upper bound, and the adjustment factors need to bring them down.[23]

Our strategy to obtain a consistent and comparable vision of the period in both countries is based on contrasting the "level of reporting" of the variables in both methods. As described above, we have gathered some additional data for the two countries, so that we have the same period covered by both LBIO and surveys in both Finland and Sweden. Since we have LBIO data for Sweden over 1970-2013, we conducted a survey for all innovating firms (for the later years, 2009-13).[24] And conversely, because the Finnish data was gathered by surveys in

[22] Values around and over 50 percent in the early 1990s, and some below 20 percent around the year 2000.

[23] The positive self-selection would specially be the case in the Swedish survey we conducted for this paper, since it was stated that we had support from VINNOVA, who might have funded some of these firms. The self-selection effect turned out to be as expected (see next subsection). It also turns out to be the case for research collaboration, although this needed not be expected in advance (but there is some positive correlation between both variables).

[24] It would not be realistic to expect to get good responses from firms having introduced innovations in the 1970s: they might not longer exist or the involved persons might have left and not be traceable.

1985-2013, we collected the information from articles by using LBIO method for those years. The information and communication technology sector (ICT) was chosen for this exercise, because of its large role in the two economies today and for the catch-up of Finnish innovation counts to the Swedish (Giertz et al., 2015; Halme et al., 2015; Kander et al., 2016).[25] In this way, we are able to contrast both data assembling methods and construct accurate adjustment factors.

We proceed by estimating the "level of reporting" of the public variables in LBIO.[26] This is obtained as the ratio between the shares of observations with e.g. public funding in LBIO and the survey, respectively. The inverse of this relationship gives us an "adjustment factor" with which we can estimate a comparable series of "percentage of innovations with public stimulation (of type x)" for the whole period, and for all sectors (see table 4). Conversely, to get the same series out of survey data, we use the relationship in the shares between respondents and the full sample, to account for the possible self-selection effect. The procedure is explained in further detail in equations 1 to 4.

Define PF_{ij} as the percentage of innovations receiving Public Funding in country *i* and year *j*. For this variable we have two different sources, namely the survey and the LBIO data. We calculate the "level of representation" L_i with the following ratio:

$$L_{i\_PF} = PF_{i\_LBIO} / PF_{i\_SURVEY} \quad (1)$$

This ratio is not calculated year by year, since we do not have enough data to ensure significant results. We average for the whole period or for different sub-periods.

Next, we define our adjustment factor for the LBIO data as the inverse of this "level of representation", as U_i (since it is expected to be an upscaling factor):

$$U_{i\_PF} = 1 / L_{i\_PF} \quad (2)$$

In the case of the adjustment factors for departing from survey data, they are defined using the relationship between the whole sample and the sub-sample of respondents, in their LBIO data. We denote this relationship as R_i because it derives from self-selection into responding the survey.

[25] The sector was defined with the same criteria as in Kander et al. (2016), to include SNI codes 30-33, and 72. SNI 30: computers and office machinery; SNI 31: electrical apparatus, e.g. batteries, circuits and electric motors; SNI 32: telecommunication equipment; SNI 33: electronic equipment; SNI 72: software. This criterion was applied using the classification of the innovations themselves, not to that of their commercializing firms. The total number of ICT innovations in the dataset is 2,506, of which 888 from Finland and 1,618 from Sweden.

[26] It is assumed here that the responses of firms to the survey are correct, although there certainly will be some error. But in the surveys, firms are asked directly about public funding (for example), whereas we cannot be sure that they are asked about these aspects by the journalists writing the articles on which LBIO is based.

$$R_{i\_PF} = PF_{i\_RESPONDENTS} / PF_{i\_ALL} \quad (3)$$

Again, we average across sub-periods. Similarly to above, the adjustment factor for survey data is again defined as the inverse of the relationship in equation 3), and it is expected to be a downscaling factor, therefore named D_i:

$$D_{i\_PF} = 1 / R_{i\_PF} \quad (4)$$

Equations 1-4 are given in terms of the Public Funding variable, but in all cases a parallel procedure is followed for collaboration for Public Research. Table 4 below provides a summary.

Table 4: Calculation of adjustment factors

For estimation departing from…	Relation used	Expected value
LBIO	Survey / LBIO (respondents)	U > 1
Survey	LBIO all innovations / LBIO for survey respondents	D < 1

Source: authors.
In both cases, the numbers we are dividing are the percentage of innovations with type x of public stimulation (x being funding or research collaboration) obtained according to each method for each country and period.

The application of this procedure rests on a set of plausible assumptions, which are presented and discussed in Appendix 1.

We chose to estimate adjustment factors only for public funding and research, since the information available on the impact of public regulation and procurement is rather scarce and does not allow such estimation.[27]

Survey results from Sweden. ICT sector, 2009-2013

The sample of ICT innovations introduced in Sweden between 2009 and 2013 amounts to 242. Our database contains information on the contact person whenever this was mentioned in the articles (normally, the CEO or an R&D manager). These names have been searched for on the web, with a success rate of 82% in finding valid e-mails – in some cases, the person

[27] An attempt was made at estimating scaling-up factors for public regulation and procurement altogether, in the variable ”Public demand”. We haven't been successful in this, however. There are too many zeros in the data (country-years where we have no cases of these public actions), and the resulting scaling-up factors would be implausibly high.

listed as a contact for the innovation had changed workplace or was untraceable. 16 additional surveys were sent over Linkedin. The sub-sample of contacted firms was finally 208.[28]

The survey was kept as similar as possible to the Finnish ones (VTT, 1999). It had a total of 38 questions, of which some are exploited here and others are left for further research. It was sent as an on-line questionnaire in September 2016, using the SUNET software available from Lund University, and kept open during 6 weeks. We received a total of 68 answers (33 percent response rate).

The results are shown in table 5. As was expected, all variables are much higher in the survey-based estimates than in the LBIO data: for example, we obtain 68 percent in public funding versus 9 percent. Part of this difference can be attributed to the effect of self-selection into responding: innovations for which we got a response were more likely to have had public funding (for example), already according to LBIO (14 percent in this case – compare the second and third sub-parts of table 5).[29]

But selection is only a small part of the story. When dealing with the same sub-sample of 68 observations, the level of representation of public funding is 22 percent (i.e., in only one out of five cases where public funding was received according to the survey, did the articles mention it). This representation level is 24 percent when it comes to public research, and 29 percent in terms of the general public stimulation variable. Such is the extent of the bias in the LBIO method against this kind of information, which needs do be dealt with.[30]

Table 5: Public stimulation in Swedish ICT innovations, 2009-13. According to method

Survey data (68 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.809	.048	.713	.905
Public Funding	.683	.059	.564	.801
Public Research	.529	.061	.408	.651
Public Demand	.279	.055	.170	.389
LBIO data, respondents (68 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.235	.052	.132	.339

[28] Actually, the number of firms is slightly lower, since some have more than one innovation in the sample. 208 is the total number of surveys sent out, while some may have been addressed to different persons in the same firm, or even the same one. The search for contact information was performed by the SWINNO project assistants Linnea Karlsson and Mathias Johansson.

[29] These differences within the LBIO data, however, are not significant because of the high standard errors.

[30] We are also conducting a related exercise of matching with project data from the funding agency VINNOVA; so far, for one program, Vinn Nu. This showed a similar representation level of public funding of 22 percent in all sectors in 2002-13.

Public Funding	.147	.043	.061	.233
Public Research	.132	.041	.050	.215
Public Demand	0	-	-	-
LBIO data, all (242 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.186	.025	.137	.235
Public Funding	.091	.019	.054	.127
Public Research	.107	.020	.068	.147
Public Demand	.012	.007	-.002	.026

Source: UDIT dataset and survey of ICT Swedish innovators, 2009-13.

Note: one observation always means one innovation. The second sub-part of the table reports the LBIO-based statistics of the same sub-sample of innovations for which we got a survey response. In this and the third sub-part, one observation does not correspond to "one response", in the sense that it might have been derived from one or more articles.

The collection of additional data also allows us to compare Finland and Sweden directly with the survey information, restricting ourselves to the ICT sector in the period 2009-13. This is shown in Appendix 2.

LBIO results from Finland. ICT sector, 1985-2013

To ensure comparability an additional investigation of the articles for the Finnish ICT innovations in the data set was undertaken. This allows a contrast across LBIO and survey methods for Finland, shown in table 7. The results coincide with those obtained for Sweden: according to the surveys, the public sector was involved in a higher percentage of innovations than when resorting to LBIO. The level of representation of the public variables in this case is of 26 percent for funding, 29 percent for research, and 35 percent for public stimulation of any kind. According to this, trade journals in Finland would be slightly more likely to mention the role of the public sector in the innovations they wrote about over the period.[31]

Also again, a small part of this difference is explained by the selection into responding (for example, 21 versus 16 percent in funding for respondents versus the general sample – but none of these differences are statistically significant).

[31] See Appendix 4 for the changes in reporting behaviour of journals over time.

Table 7: Public stimulation in Finnish ICT innovations, 1985-2013. According to method

Survey data (177 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.944	.017	.909	.978
Public Funding	.797	.030	.737	.856
Public Research	.791	.031	.730	.851
Public Demand	.475	.038	.400	.549
LBIO data, respondents (177 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.328	.035	.258	.398
Public Funding	.209	.031	.149	.270
Public Research	.232	.032	.169	.294
Public Demand	.034	.014	.007	.061
LBIO data, all (713 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.271	.017	.238	.303
Public Funding	.157	.014	.130	.184
Public Research	.174	.014	.146	.202
Public Demand	.042	.008	.027	.057

Source: UDIT database and LBIO investigation of ICT Finnish innovators, 1985-2013.

Note: one observation always means one innovation. The second sub-part of the table reports the LBIO-based statistics of the same sub-sample of innovations for which we got a survey response. In this and the third sub-part, one observation does not correspond to "one response", in the sense that it might have been derived from one or more articles.

The collection of additional data also allows us to compare Finland and Sweden directly with LBIO information, restricting ourselves to the ICT. This is done in Appendix 2.

The adjustment factors

The next step is to use the relationships found between LBIO and survey data in the ICT sector to estimate comparable time series for both countries and the whole period. Table 10 shows the adjustment factors derived and applied. The first are scaling-up factors: resulting from the ratio between the mean values for respondents in the survey and LBIO data, they will be used to adjust upwards the series stemming from LBIO (and correspond to the inverse of the "level of representation" of each variable as explained in the previous subsection). The second are scaling-down factors: they arise from the relation in LBIO between respondents and the general sample, and will be used to make estimations departing from survey data, to simulate the results of a survey with full response (only for Finland, 1985-2013).

As can be seen, because the bias in the articles was found to be a little lower in Finland than in Sweden (representation level of 26-29 percent versus 22-24 percent for funding and research respectively), we are adjusting the Finnish data with slightly lower factors (around 3.6, while the Swedish are at or over 4). The survey data will be downward adjusted multiplying by 0.75.

Table 10: Adjustment factors

<table>
<tr><td colspan="3">For estimation departing from LBIO:
ratio survey / LBIO (respondents)</td></tr>
<tr><td></td><td>Finland,
1970-84</td><td>Sweden,
whole period</td></tr>
<tr><td>Public Finance</td><td>3.81</td><td>4.64</td></tr>
<tr><td>Public Research</td><td>3.41</td><td>4.00</td></tr>
<tr><td colspan="3">For estimation departing from survey:
ratio LBIO all / LBIO respondents</td></tr>
<tr><td></td><td colspan="2">Finland,
1985-2013</td></tr>
<tr><td>Public Finance</td><td colspan="2">0.75</td></tr>
<tr><td>Public Research</td><td colspan="2">0.75</td></tr>
</table>

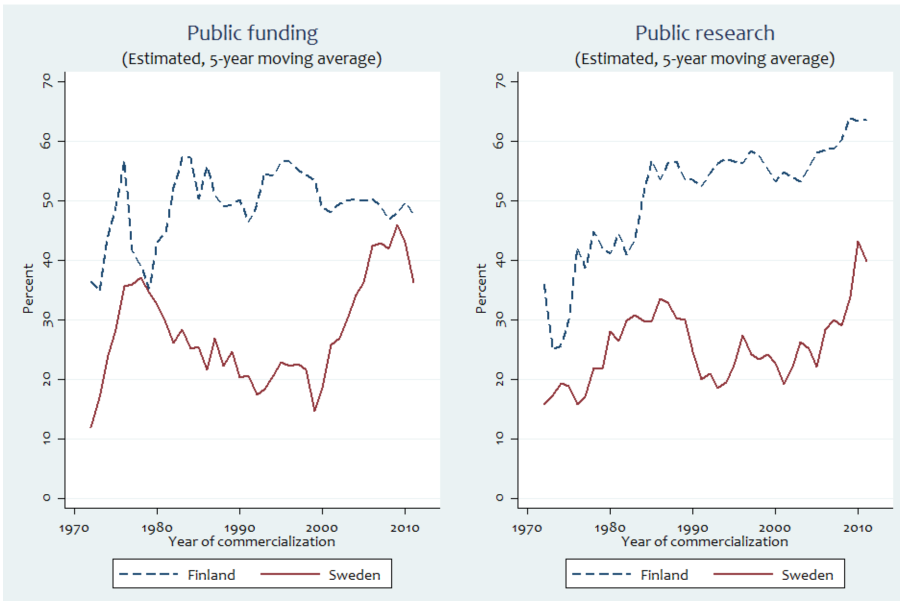
Source: authors' calculations.

Results: the public stimulation of innovations in Finland and Sweden

The results from our study suggest that the role of the public sector in supporting innovation has been substantially larger in Finland than in Sweden. Figure 3 below presents our estimated series as 5-year moving averages. The lines show the percentage of innovations which received public funding or were developed in collaboration with public research, in each year, in Finland and in Sweden.

Constantly over the study period the share of innovations with public support (either in the form of funding or research collaboration) has been higher in Finland than in Sweden. As can be seen in figure 3, in Finland 35-55 percent of the innovations have been stimulated by public funding whereas in Sweden the respective share has shifted between 10 and 45 percent. Similarly, the share of significant innovations that have benefitted from collaboration with public research has in Finland been between 25 and 65 percent whereas in Sweden it has been in the range of 15 to 40 percent. The difference is strikingly large (40 percentage points at maximum, in the innovations from the years 1990 to 2000).

Figure 3: Percentage of significant innovations that received public funding or were developed in collaboration with public research. Finland and Sweden, 1970-2013 (estimated)



Source: authors' calculations.

We can also point to changes over time in both countries. In terms of the share of innovations stimulated by public funding, in Finland the trend is quite constant from the mid-1980s onwards (around 50 percent), while for Sweden it is much more volatile, with a strong decline since the early 1980s and until the late 1990s, followed by even stronger upsurge. This fraction is also closely related to the overall performance of innovation in Sweden, which saw a decline in the 1980s and a surge from around 1990 (remember figure 1). The Swedish trendline naturally raises questions in terms of factors that lie behind such dramatic changes. Certainly, they are not directly explained by variations in the levels of public R&D funding, as these have not experienced such large and drastic ups and downs (remember figure 2, and see further discussion in section 6.1). Furthermore, since innovation takes time, one cannot expect a direct link between public funding and the share of innovations that received such funding in nearby years. Indeed, the changes in funding levels have sometimes even been in the opposite direction to the shares of innovations that received such funding: for instance in the 1980s direct government funding to business R&D grew constantly in Sweden, while the share of publicly stimulated innovations declined dramatically. The strong rise of publicly stimulated innovation during the 2000s coincides with the establishment of VINNOVA (in

2001), but again the time lags involved makes it difficult to suggest with any certainty that there was a causal relation.

With respect to the share of innovations stimulated by collaboration with public research, Finland has had a relatively steadily raising trend, which is in line with the overall national policy guidelines. There was an abolishment of limitations regarding contract research between universities and industry in 1970s (Raatikainen and Tunkkari, 1991), which paved the way for such an increasing trend. Furthermore, the strengthening of university-industry collaboration has been one of the cornerstones of Finnish research and innovation policy, and its weight has increased over time (Lemola, 2003; Nieminen and Kaukonen, 2004; Kutinlahti, 2005). In Sweden, the trend is more volatile, raising from the early 1970s until late 1980s, but then followed by a sudden decline between the late 1980s and early 1990s.

In the following, we discuss our results in more detail, linking them to certain aspects of the overall policy evolution and institutional characteristics of the research and innovation systems in the two countries, as well as relating them to other comparative data on public R&D funding and innovation collaboration.

Explaining the differences in public funding

Regarding the role of public R&D funding, our results are largely consistent with those of the Community Innovation Survey (CIS). According to CIS, a substantially higher share of innovative companies have received public funding in Finland than in Sweden (see figure A5.1 in Appendix 5). For instance, in 1996 only 13 percent of innovative companies in Sweden had received public R&D funding, while in Finland the respective share was 48 percent.[33] Compared to our results, the shares provided by CIS data are somewhat lower for both countries, but the difference between them is quite similar. The numbers, however, are not directly comparable, since they have both conceptual and sample differences. Firstly, our results refer to *innovations*, while the data from CIS refers to *firms*. And secondly, CIS is restricted to companies with ten or more employees, while in the UDIT database smaller companies are included as well (and indeed they are responsible for a significant part of the total number of innovations: 32.4 percent of the Swedish and 18.4 percent of the Finnish). So the distinction between Finland and Sweden holds also in smaller firms, including start-ups, and in a sample of most significant innovations obtained from an object-based perspective.

What could then explain this large difference in the significance of public funding for innovations between Finland and Sweden? We start looking at the levels of private and public R&D funding in the two countries (recall figure 2). It is an established fact that the Swedish

[33] CIS provides comparative data on this aspect only for four years (1996, 2000, 2012, 2014), and a longer time span is not available. However, for each year Finland has a substantially higher share.

economy has over time been more endowned with private capital compared to the Finnish economy, where shortage of capital was a feature characterising the innovation environment still during the 1980s (OECD, 2005). Furthermore, and perhaps as an indication of this, companies' own R&D expenditures per capita have been substantially higher in Sweden compared to Finland, especially from the early 1980s until 2001 (figure A5.2 in Appendix 5).[34] This is in principle in line with our results, as Swedish companies have been able to invest significantly more in R&D (at some periods nearly three times more per capita), and therefore the role of (and need for) public R&D support may not have been so significant.

Secondly, and perhaps more importantly, the level and allocation of public R&D funding is definitely a crucial factor and seems here at first glance to conflict with our findings, since the level of direct public funding to companies' R&D has been substantially higher in Sweden compared to Finland. So uncritically we would expect that Swedish innovations had been stimulated by public funding to a greater extent. Over the period from 1981 to 2013, the share of companies' R&D expenditure financed from public sources has been constantly higher in Sweden (recall figure 3), and for instance in the 1980s the share was nearly threefold and in the 1990s double compared to Finland. However, the aggregate statistics hide one important feature of publicly funded business R&D in Sweden: the lion's share of government funds are channelled via the defense agencies to the defense sector (e.g. more than 75 percent in 2013; Statistics Sweden).[35] If the defense sector is excluded, the share of public funding of companies' R&D investments has been around 1 percent in the 2000s whereas in Finland it has been slightly over 2 percent. In Finland there is no such a dominating sector and therefore, the role and significance of the defence sector is clearly a distinctive feature in the two countries' public funding for companies' R&D [36,37]

A related significant feature is that a big share of the funding provided by the defense sector agencies goes to large companies (VINNOVA, 2015, 7; Lundmark, 2010). Overall, this implies that a large proportion of public R&D funding to companies in Sweden is channelled to large companies (VINNOVA, 2015). In contrast, in Finland public R&D funding to companies has been strongly targeted small and medium sized companies (SMEs) and in recent years this trend has become increasingly accentuated. In practice these differences in target populations may mean that in Sweden public R&D funding is channeled

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[34] Somewhat surprisingly, the situation was the opposite for the years 2007-2011, mainly due to declining private R&D investments in Sweden.

[35] Traditionally Sweden has a relatively large defence industry the roots of which relate to its traditional policy of neutrality and non-alliance. In order to achieve autonomy and self-sufficiency in terms of defence equipment and technology, Sweden has invested strongly on defence R&D (Ikegami, 2013).

[36] Another factor that may play a role here is that innovations in the defence sector may be kept secret and hence not published about in journals, what would hinder their inclusion in our database.

[37] There is also another source of difference looming in the statistics: the data on government R&D funding for business enterprises in Sweden also includes the funds to the industrial research institutes, which legally are organised as limited companies. In Finland government funding to public research institutes is not covered in these numbers.

to a smaller group of large companies while in Finland a larger number of companies have over time been able to receive public R&D funding.

In addition to the focus sectors of public R&D funding, another important factor that distinguishes the countries may relate to how the allocation of public R&D funding to companies is organised.. As indicated above in section 3, the Swedish R&D funding landscape has been populated by a relatively complex web of actors (see also VINNOVA, 2015, 178-180). The Swedish institutional set-up is highly fragmented and tends to lead to *"too many, too similar and often too small interventions that rely on proven instruments or are too co-ordinated"* (OECD, 2013, p. 236). Moreover, it has been argued that fewer but larger programmes tend to be more effective in terms of outcomes than large number of smaller initiatives (ibid.). In contrast to Sweden, in Finland public funding to company R&D has been channelled almost uniquely through Tekes since its establishment in 1983.[38] Furthermore, in Tekes' activities, supporting companies' R&D has always been central and for instance in 2013 around 60-65 per cent of Tekes funding went to companies (OECD, 2013, p. 225). In contrast, of VINNOVA's funding only around 30 per cent is directed to companies (ibid.), which is surprising given the agency's original mission of supporting industrial development and economic growth (cf. Persson, 2015, p. 171). Overall, the difference in these organisation models is significant and might have an impact on innovation outcomes.

Explaining the differences in collaboration with universities and public research institutes

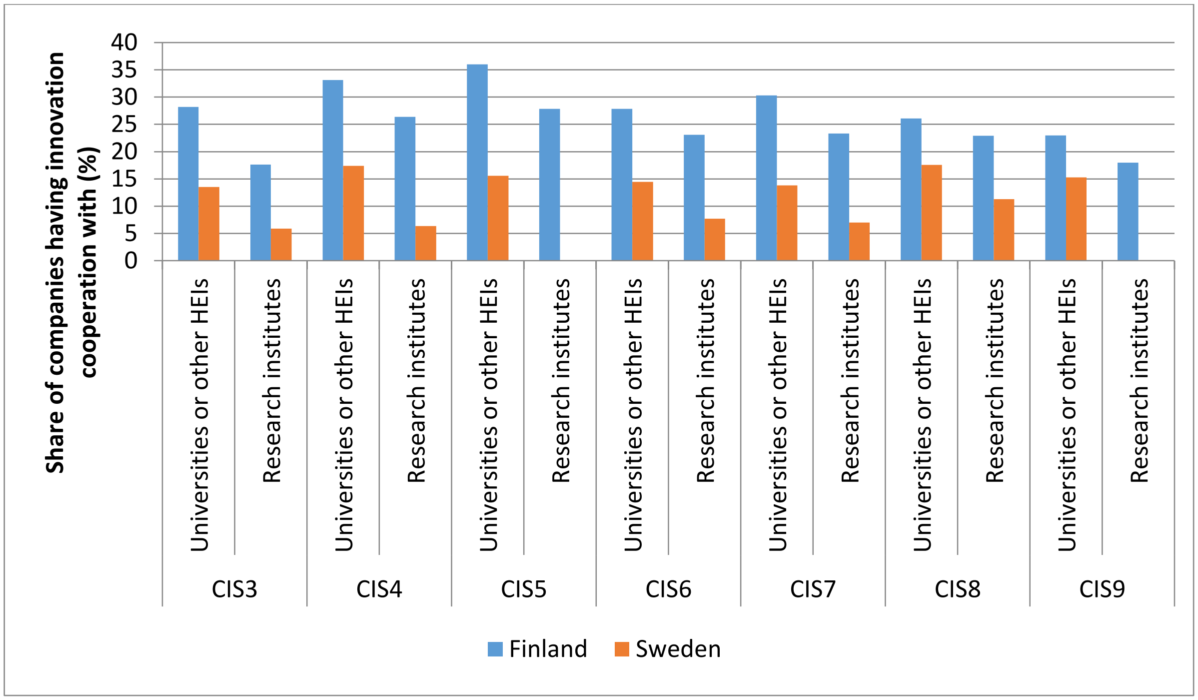
Regarding innovations stimulated by collaboration with public research, our results are also in parallel to those of the CIS[39] and some other comparative studies (e.g. Cunningham & Link, 2015). According to CIS data, over the period of 2000 to 2014 the share of companies that have had innovation cooperation with universities or other higher education institutions has varied in Finland between 25 and 35 percent approximately (figure 4 below). In Sweden, the corresponding share has been more constant, at around 16 percent. In terms of innovation collaboration between private companies and public research institutes, the difference is similar: 18-28 percent for Finland and 6-11 percent for Sweden. Compared to our results, the difference between Finland and Sweden appears a bit lower in the CIS data, but points in the same direction: Finnish collaboration between private firms and public universities and

[38] The share of Tekes in public funding to company R&D lied at 71 per cent for the period 1985-96, and 83% in 1997-2017 (authors' calculations with data from Statistics Finland). For VINNOVA, the corresponding value is 14 percent in 2001-14 (subsidies from VINNOVA's yearly reports, in relation to BERD from OECD).

[39] There are some differences in the focus of the our approach and the CIS questions related to collaboration – our method concentrates on collaboration in the development of a particular innovation, while CIS focuses on cooperation in any innovation activity of the company.

research institutes leading to innovations has been more common than the Swedish. As was the case with public funding, this holds for samples that have been constructed in different ways, and include also very small firms in the case of our UDIT data.

Figure 4. Share of companies having innovation cooperation with universities or other higher education institutes and reseach institutes, 2000-2014



Source: Community Innovation Survey.

Note: CIS 3 covers years 1998-2000, CIS 4 2002-2004, CIS5 2004-2006, CIS6 2006-2008, CIS7 2008-2010, CIS8 2010-2012 and CIS9 2012-2014.

Certain aspects of differences in collaboration are clearly linked to the institutional characteristics of the research and innovation systems in the two countries. Research institutes play a weak role in Sweden, as discussed in section 3 above (see also OECD, 2013, 189-191). While pre-competitive research has been concentrated at universites in Sweden, public research institutes have been significant since their establishment in the World War II in Finland (Loikkanen et al., 2009). In particular, the large research institute VTT, which is close to industry and collaborates extensively with companies, has played an important role in Finland.

On a more general account, it has been pointed out that the links between traditional universities and industry, especially SMEs, are weak and insufficient in Sweden (OECD, 2013, 20; Braunerhjelm et al., 2003).

Tekes has played a very significant role in Finland in encouraging and pushing companies to collaborate with universities and public research institutes (e.g. Hyytinen et al., 2009, pp. 32-35). Compared to the Swedish counterpart, VINNOVA, Tekes acts much more with a strategic top-down approach within its programmes (Halme et al., 2016), which have been an effective instrument to intensify the collaboration between companies and universities and public research institutes (Lemola, 2002; Van der Veen et al., 2012).

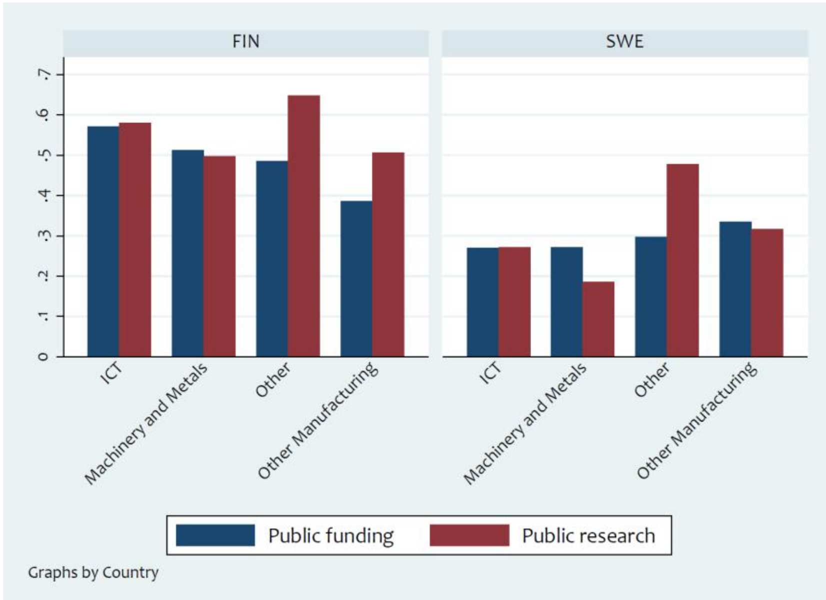
Public funding and research by sectors

Are there any significant differences in the extent to which the sectors benefit from public stimulation? We have tried to answer this question diving the dataset into the following four subcategories: 1) Metals and machinery, 2) ICT, 3) Manufacturing industry except metals, machinery and ICT and 4) other sectors, mainly services, agriculture, forestry and mining.[40] For each sector, we have estimated the percentage of innovations that have received each kind of public support during the period, using the adjustment factors derived above. The results are shown in figure 5.

The levels of public stimulation do not appear to differ very strongly between these widely defined sectors. The ranking looks, however, different in Finland than in Sweden when it comes to involvement of public funding. While ICT is the sector whose innovations look more dependent on the public sector in Finland, the opposite is true in Sweden. The numbers should be interpreted with care, however, since the margin of error in the estimations is quite high. In public research, both countries show a higher implication of the public institutions in our residual category "Other" innovations. This would be driven to some extent by the "Technical consultancy" subsector in the case of Finland, and in Sweden also by "Textiles" and "Foodstuffs".

[40] This subdivision is taken from Kander et al. (2016). We use the product codes and the following NACE classification: ICT NACE 30-33 and 72, Machinery & Metals NACE 27-29, Other Manufacturing NACE 15-26 and 34-37.

Figure 5. Percentage of innovations benefiting from public funding or collaboration with public research, by sectors, 1970-13 (estimated)



Source: authors' calculations.

Publicly stimulated innovations more novel and important

Finally, our results also reveal an important finding related to the significance of public interventions: innovations that have been stimulated by public support (in the form of funding or collaboration with public research) tend to be more novel than innovations in general (i.e. in the whole sample). See table 11 below, where some indication of this is given for the ICT sector, using a variable that indicates the technological novelty of the innovation for the firm that developed it. Of all ICT innovations in Finland 69 percent were totally new to the firm, but within those that received public funding 85 percent were totally new. The contrast is even stronger for public funding in Sweden: half of all innovations were totally new to their firms, but over 80 percent of those stimulated by public funding fall within the same novelty category. This pattern is constant also in terms of collaboration with public research in both countries, and hence potentially points to a significant impact of public stimulation.

Table 11. Novelty of publicly-stimulated innovations in the ICT sector (1970-2013)[41]

	Finland (830 obs)				
	All data	Public funding	Public research	Ratio funding	Ratio research
Totally new	68.8	85.2	81.0	1.24	1.18
Major improvement	24.7	14.1	19.0	0.57	0.77
Incremental improvement	6.5	0.7	0.0	0.11	0.00
	Sweden (1,591 obs)				
	All data	Public funding	Public research	Ratio funding	Ratio research
Totally new	50.2	80.9	59.6	1.61	1.19
Major improvement	39.3	18.1	37.6	0.46	0.96
Incremental improvement	10.5	1.1	2.8	0.10	0.26

Source: UDIT database. LBIO data.

This finding confirms the results of the few previous studies referred to in section 2 that have analysed innovation policy impacts through outputs (Beck et al., 2014; Czarnitzky et al., 2007; Guo et al., 2016). These studies have found that public support tends to increase the "quality" of the innovations. However, what is worth stressing, is that these previous studies have only examined the role of public funding, while our results suggest that such a pattern also holds for collaboration with public research.[42]

We have also posed the question whether publicly-stimulated innovations are of higher "significance", in the sense that they would have bigger expected or effective impacts on society, at different levels. The concept of "significance" is multidimensional and difficult to define. We approach the issue here with the number of articles dedicated specifically to the innovation that appeared in the journals in our LBIO sample. a higher number of articles would indicate that an innovation was perceived as important by the connoisseurs, and in that sense gives us an approximation to the expected societal impacts. In table 12 we report the results of this exercise for Sweden.

The majority of Swedish innovations in the UDIT database have one article dedicated specifically to them (76.8 percent). A small part (7.1 percent) derive only from an article

[41] This table is based on LBIO data. Therefore, if we are to extrapolate the results, we need to assume that the innovations in which public stimulation was present but unknown of would follow a similar distribution.

[42] It should be noted that there might be a role for firm size in this result: smaller firms are more likely to get public funding (since they are specially targeted in some funding programs), and they would also tend to have more narrow competence areas, so it would be easier for a new project to fall out of these and thus be more novel to the firm. Further work will aim at disentangling this.

providing a sectoral overview, while 16.5 percent have two or more dedicated articles. The share of innovations with public stimulation in the database, according to LBIO, was 13.1 percent (which we have upwards corrected to 45 percent). But for innovations with two articles dedicated, the corresponding figure is 19.1 percent, while it increases to 21.8 percent for innovations with articles, and 40.5 percent for those with four or more articles. The same pattern is also present specifically for public funding and research collaboration. It points to the fact that the innovations resulting from public stimulation were perceived, ex ante, to be more significant than the ones where the public sector did not participate.

Table 12. "Significance" of publicly-stimulated innovations in Sweden, all sectors (1970-2013)[43]

	Whole database		Percentage of innovations for each "article count" category		
article count	Number of observations	Percent	Public stimulation	Public funding	Public research
0	289	7.1	7.7	2.5	4.6
1	3 137	76.8	11.6	5.2	5.6
2	461	11.3	19.1	9.1	10.4
3	124	3.0	21.8	14.5	11.3
4 or more	89	2.2	40.5	28.1	22.5
All	4 083	100.0	13.1	6.2	6.6

Source: UDIT database.
The table displays the cross-distribution of public stimulation, public funding, and public research collaboration with the "article count" variable (number of articles dedicated specifically to an innovation in the journals).
Note: these numbers are not available in the Finnish data.

Concluding discussion

This paper studies the role of the public sector in stimulating innovation output in two of the leading innovative economies of the world; Finland and Sweden. We depart from a new database of significant innovations in both countries, carefully homogeneized to follow the same selection criteria and definitions, and study two forms of public stimulation: public funding of innovations and collaboration between private firms and public research institutions.

[43] A limitation of this exercise is that it is again based solely on LBIO (because we have no identification of the firms who received each kind of support out of the ICT sample for 2009-13). So again we need to rely on the assumption that the distribution would have been the same if we could include all the cases of innovations which got public funding, or resulted from collaboration with public research institutions.

We have shown that, when it comes to role of the public sector in the development of innovations, the LBIO method is insufficient, because it is likely to give us a lower-bound for the levels of public stimulation. On the other hand, surveys provide us with an upper-bound of public stimulation. Our methodological contribution lies in combining LBIO and surveys, which allows us to estimate adjustment factors for correcting the levels and trends to more realistic ones. Doing so, we are able to calculate a consistent series of the levels of public stimulation of innovations in both countries over a long time: 1970-2013.

Our results suggest that the public sector played a prominent role in funding and research collaboration leading to top innovations in both countries. The numbers are substantially higher for Finland: 30 to 50 percent, than for Sweden: 15 to 35 percent. The difference is specially large in the years between 1990 and 2000, when we see a drop in the relative role of the Swedish public sector in innovation output, while the Finnish trends are constant or slightly increasing over the period.

That Finnish innovative activities more often stem from collaboration with public research institutions than Swedish is also confirmed by the Community Innovation Surveys from 1998 onwards. Our novel contribution compared to CIS is that we confirm the same image, based on actual innovations, also for small companies that are omitted in the CISs, and that we assess a robust quantitative difference with annual data 1970-2013. We can thus trace the evolution of the public research collaboration in stimulating innovations over a longer time period, and we find that the Finnish impact from public research on innovations increased steadily since 1980, while the trend for Sweden is more volatile, with a severe drop from the mid 1980s to the early 1990s.

That public funding of significant innovations also has been more important in Finland than in Sweden comes perhaps as more of a surprise. OECD figures indicate that actually Sweden is investing several times more public money into innovation than Finland, but those figures are difficult to interpret since 75-80 percent of the Swedish public funding of R&D goes to defense research and development, while the corresponding share in Finland is negligible. Most of that funding goes to a few large companies, and perhaps some of the innovations that come out are classified as secret by the companies and hence do not reach the journals we have scanned. CIS also points to a substantially larger share of the innovative firms in Finland having received public funding than in Sweden. The Swedish funding landscape has been much more complex and probably less efficient than its Finnish counterpart, even if its organization has been rationalized over time, with the establishment of Vinnova and mergers of small agencies. This rationalization of the Swedish funding landscape is reflected in the strong catch-up of Sweden in the public funding variable since 2000, and in the most recent years the levels are almost the same: around 40 percent of the significant innovations did receive public funding in both countries.

The stronger role for the public sector in Finland than in Sweden in stimulating innovations leads us to consider whether this had any relations to the catch-up process that we see happening during this time, where Finland catches up with Sweden, both in terms of innovation output and GDP per capita. Given that Finland is a smaller country, innovation per capita was actually higher there at the end of the period (Kander et al., 2016). Was the larger role for public stimulation a result of the backward comparative position of Finland in the beginning of our period? A residual role of the public institutions seems consistent with the aggregate trends in R&D, where the private contribution to funding increased while the public one stayed quite constant in relation to GDP (remember figure 2). But the shares of innovation resulting from public stimulation in Finland did not decrease at the end of the period, as could have been expected. Was the "entrepreneurial state" an agent for the Finnish convergence with Sweden in innovation output – or overtaking (cf. Mazzucato 2013)?

Mazzucato (ibid.) has argued for an important role of the public sector in promoting innovation, summarizing the rationales for government action and reviewing many cases of successful public endeavours in innovation. Lerner (2013) similarly stresses that *"In many cases, there is likely to be a role for the government in stimulating a vibrant entrepreneurial sector, given the early stage of maturity of these activities in most nations"* (p. 78), thus attributing singular importance to public institutions in comparatively less developed countries. He also points, however, to the many risks of introducing badly designed programs, which might even be counterproductive – something that further work will consider in more detail.

It is to be remembered that this study does not cover the full scope of public policy for innovations, but only considers impact of supply measures directly tied to companies' R&D activity. Other policies, such as investment in basic research, regulation and public procurement, or the education of the labour force, obviosly lie outside of the scope of this study, but certainly are important as well (Stiglitz, 2015). The main point of here is that public stimulation of innovation has played a crucial role for actual innovation output, also in a more direct and limited sense, in both Sweden and Finland.

Future work on the UDIT database will be directed at introducing public agencies' micro-data, allowing to test for matches between innovations in our sample and funding projects awarded to firms; some preliminary work has been undertaken on this with respect to the Vinnova program Vinn Nu. There will also be an emphasis on going beyond the sheer number of significant innovations and try to ascertain their societal relevance – i.e., whether they promoted increases in the general standards of living and wellbeing or had less desirable social consequences.

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Appendices

Appendix 1: Assumptions for the scaling-up procedure

This paper applies scaling-up factors to the series of percentage of innovations with public support of each kind, in order to correct for the under-reporting of the role of the public sector in LBIO, and the possible over-reporting in survey data (because of self-selection into responding). Our estimation rests on the following set of assumptions:

1. The under-representation of public stimulation in LBIO is the same across sectors in the economy, and thus it is valid to use the ICT to extrapolate this relation onto the others. Appendix 3 provides a robustness check for this assumption, on the basis of additional Swedish data.

2. The under-representation of public stimulation in LBIO is constant: for Sweden, taken from ICT in 2009-13, for Finland, taken from ICT 1985-2013. Appendix 4 provides a robustness check for this assumption, on the basis of Finnish data.

3. The under-representation of public stimulation in LBIO is the same for firms responding and not responding to the survey. This assumption needs additional hard data to be contrasted with, for example on public funding actually awarded. We plan to do an exercise on this, based on work by Sara Torregrosa on one VINNOVA program (Vinn Nu) for 2002-13, and a future analysis of funding data from Tekes for 1983-2013. Relying on the Vinn Nu data, the percentage of representation of public funding in non-respondents turns out to be 17 percent – that is, similar to that of respondents in the comparison between LBIO and the survey results, specially in the non-ICT sample.

Appendix 2: Comparing directly within the ICT sector

A comparison between both countries' ICT sectors, with survey data, is shown in table A2.1. It can be seen that Finland has higher values in all the variables, specially in public research (85 versus 53 percent). But the differences do not look as big as in the original data (combining LBIO and survey), and they are not statistically significant (at the 95% level) in the funding nor demand variables.

Table A2.1: Public stimulation in ICT innovations in Finland and Sweden, 2009-13. Survey data

Swedish survey data (68 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.809	.048	.713	.905
Public Funding	.683	.059	.564	.801
Public Research	.529	.061	.408	.651
Public Demand	.279	.055	.170	.389
Finnish survey data (46 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.978	.022	.934	1.022
Public Funding	.739	.065	.607	.871
Public Research	.848	.053	.740	.956
Public Demand	.435	.074	.286	.584

Source: UDIT dataset and survey of ICT Swedish innovators, 2009-13.

In table A2.2, we compare the ICT sector across Sweden and Finland using LBIO data. Also here, the values are higher in Finland for all variables, and the differences are statistically significant. The LBIO data is more precise because it allows for a higher number of observations, thus showing clearly the difference in levels between both countries; even though for the respective values we have to resort to estimations using surveys as well.

Table A2.2: Public stimulation in ICT innovations in Finland and Sweden, 1985-2013. LBIO data

LBIO data, all (713 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.271	.017	.238	.303
Public Funding	.157	.014	.130	.184
Public Research	.174	.014	.146	.202
Public Demand	.042	.008	.027	.057
Swedish LBIO data (1157 obs)				
	Mean	Std. Err.	[95% Conf. Interval]	
Public Stimulation	.130	.010	.110	.149
Public Funding	.065	.007	.051	.079
Public Research	.072	.008	.057	.087
Public Demand	.012	.003	.006	.018

Source: UDIT database and LBIO investigation of ICT Finnish innovators, 1985-2013.

Appendix 3. Robustness check: two-sector estimation for Sweden

Since we have used the ICT sector to estimate adjustment factors for the whole economy, our correction procedure rests upon a number of assumptions, one of which (nr. 1 in Appendix 1) states that the accuracy of reporting public stimulation in the journals should be the same across sectors. If this is not true, it might bias our estimates; for example, if for innovations in the machinery sector which received public funding this is discussed in the corresponding journals at a much higher rate than the 22-26 percent figures that we obtained for the ICT (for Sweden and Finland, respectively).

In order to check this, we conducted an additional survey of the non-ICT Swedish innovators in our database, also for the period 2009-13. This survey was directed to 268 firms, of which we successfully could contact 246 over e-mail, and got a total of 71 responses over the period 13th of February to 20th of March 2017. The response rate was thus 29 percent over contacted firms, very similar to the ICT survey and to the Finnish ones.

The results we obtained are reassuring. The levels of under-reporting of public stimulation variables for non-ICT innovations we found here (20 percent) are similar to those of the ICT ones that we used in our main estimation shown in the text (22-25 percent). Given that the confidence intervals are quite wide, the resulting scaling-up factors are not statistically different. They are shown in table A3.1 below.

Table A3.1: Scaling-up factors derived from the ICT and non-ICT Swedish samples

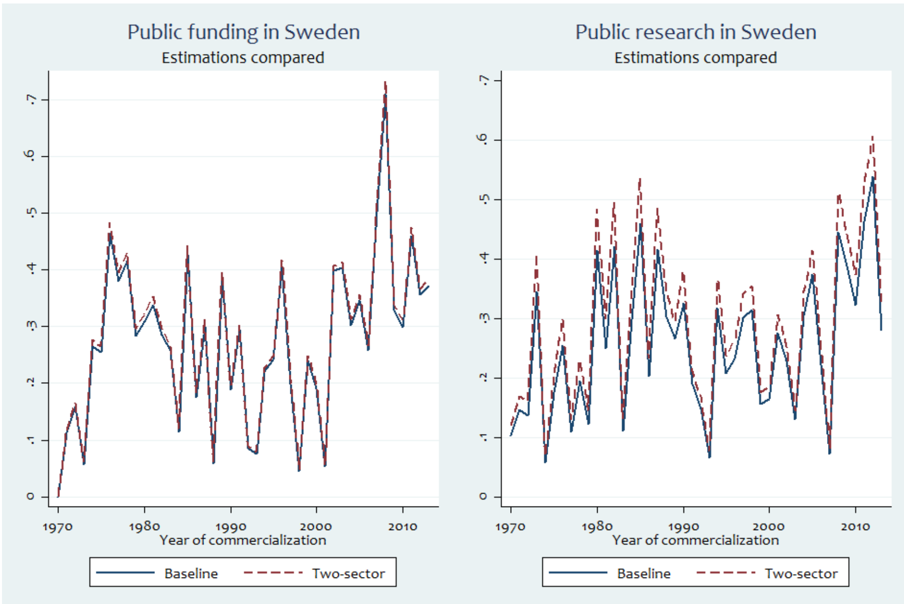
	non-ICT	ICT
Public Funding	4.90	4.64
Public Research	5.00	4.00

Source: authors' calculations with UDIT database, and surveys of Swedish innovators 2009-13.

To contrast the effect of these non-ICT factors on our estimations, we have performed an alternative estimation where the ICT and non-ICT adjustment factors are applied to the yearly data according to the shares of each sector in the Swedish sample. The ICT sector in Swedish innovations has represented an average of 40 percent over the period 1970-2013, variating between 23 and 58, and with an increasing trend. Therefore, given the higher scaling-up factors obtained with the non-ICT sample, the results of the two-sector estimate will be higher, which means that the baseline shown is a slight under-estimation for Sweden.

Figure A3.1 displays both our baseline estimation (shown in the main text), and the one deriving from the two-sector correction. It can be seen that the differences between both are really low. This confirms that we are not incurring in a grave bias when using the scaling-up factors for the ICT sector to construct estimates for the economy as a whole.

Figure A3.1: Percentage of innovations stimulated by public funding or public collaboration in research. Sweden, 1970-2013. Baseline versus two-sector estimation



Source: authors' calculations. Yearly data.

Appendix 4. Robustness check: time-variant estimation for Finland

Because in Finland we have both LBIO and survey data for the whole period 1985-2013, we can look at whether using different correction factors for different sub-periods would have a big impact on our results (thus checking assumption nr. 2 in Appendix 1). We have calculated the scaling-up factors for Finland separately for 1985-1994, 1995-2004 and 2005-2013. They are shown in table A4.1, together with the baseline joint factors we used in the main estimation.

Table A4.1: Scaling-up factors derived from different sub-periods in the Finnish data

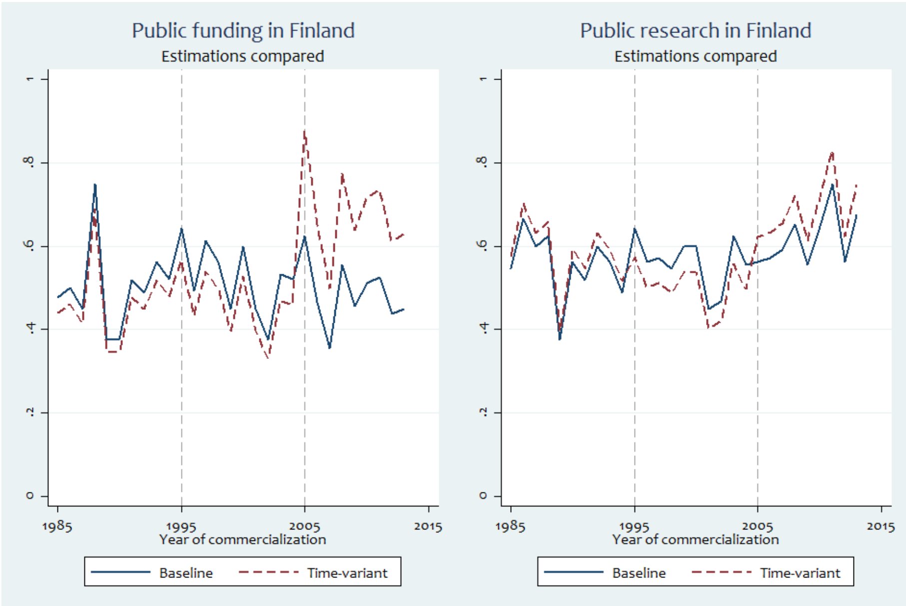
	1985-1994	1995-2004	2005-2013	1985-2013
Public Funding	3.09	3.22	6.12	3.81
Public Research	3.75	2.71	4.42	3.41

Source: authors' calculations with UDIT database and LBIO investigation of Finnish innovations 1985-2013.

To see what impact this would have on the estimated series, we have applied each factor separately to the different subperiods. In figure A4.1, the "time-variant" line corresponds to three different corrections for 1985-94, 1995-2004, and 2005-13. It can be appreciated that, in general, the check does not lead to big variations in the percentage of innovations resulting from public stimulation, or in the found trends.

This is, however, not the case for funding in the end, since the time-variant line shows higher levels in the last sub-period. Something similar happens in the research estimations, although here to a much lower extent. We could think that the latest years have apparently lower levels of reporting of public stimulations, among other things, because new articles might come up with this information in the near future. If this were the case (and not only a possible change in editorial priorities with respect to the role of the public sector), our baseline estimates for Sweden would be slightly over-estimated, because for that country we only use 2009-13 as a period of reference. This would be part of the explanation of the difference between countries in the scaling-up factors themselves (see table 10 in section 5). But, on the other hand, it reinforces our conclusion in terms of the difference between countries in the prevalence of public stimulation in innovations.

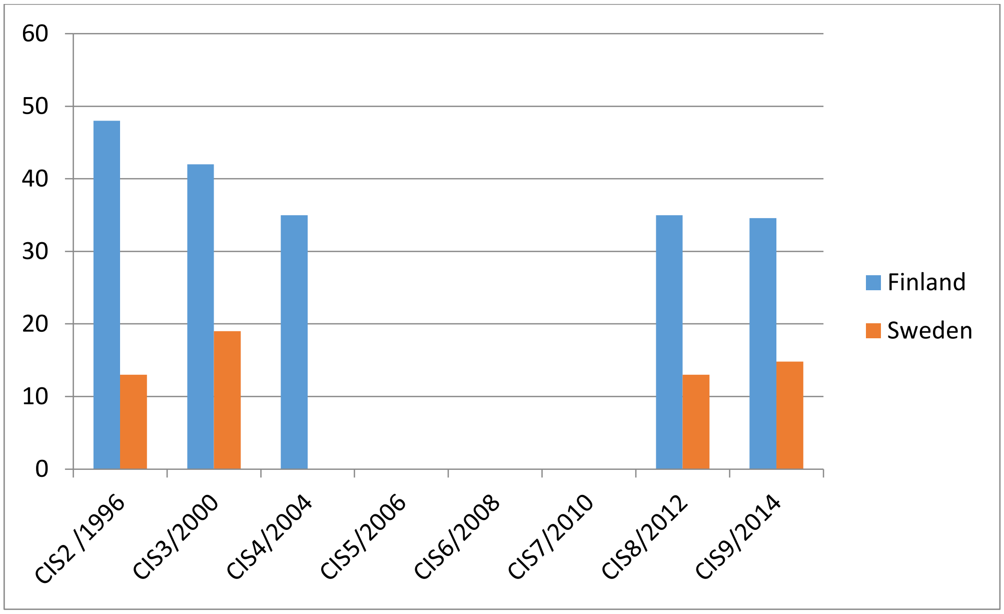
Figure A4.1: Percentage of innovations stimulated by public funding or public collaboration in research. Finland, 1985-2013. Baseline versus time-variant estimation



Source: authors' calculations. Yearly data.

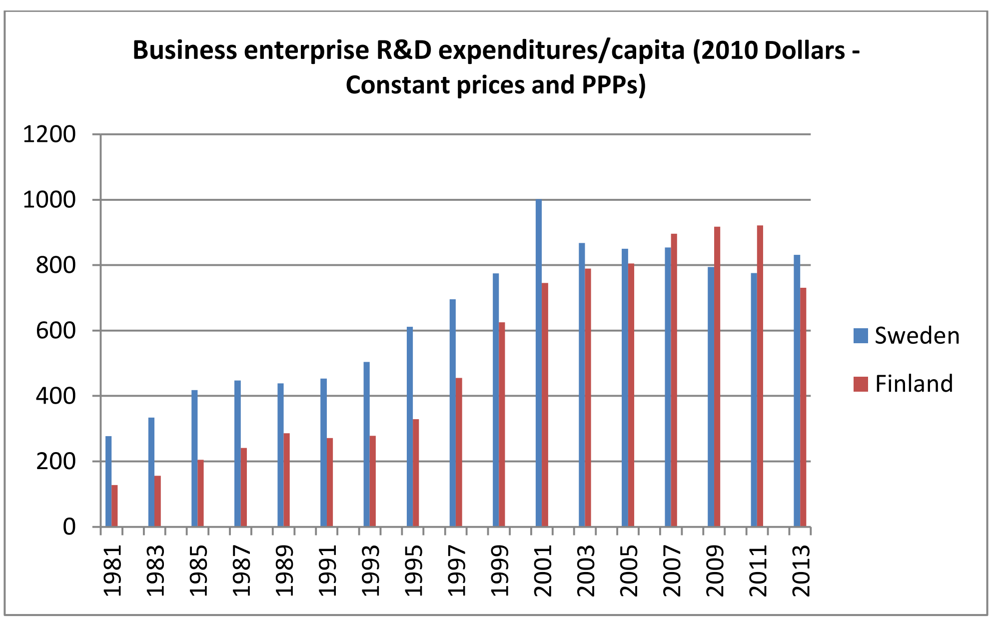
Appendix 5. Figures related to section 6.2

Figure A5.1: Share of innovative companies that have received public R&D funding in Finland and Sweden



Source: Community Innovation Survey database.

Figure A5.2: Business enterprise R&D expenditures per capita in Finland and Sweden, 1981-2013



Source: OECD.