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Shaping innovation

Studies of public funding for applied research in Sweden, 1970–2021.

Fink, Johanna

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Shaping innovation

Studies of public funding for applied research in Sweden, 1970-2021.

JOHANNA FINK

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Shaping innovation

Shaping innovation

Studies of public funding for applied research in Sweden,
1970-2021.

by Johanna Fink



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Thesis for the degree of Doctor of Philosophy

Thesis advisors: Josef Taalbi, Sara Torregrosa-Hetland

Faculty opponent: Erik Arnold

Doctoral dissertation for the degree of Doctor of Philosophy in Economic History at the Faculty of Economics and Management at Lund University to be publicly defended on Friday, 2nd of October 2026 at 10.15 in Holger Crafoords Ekonomisentrum EC3:211

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Abstract Innovation and technological progress have been identified as key drivers of long-term economic growth. However, not all innovation is supporting sustained economic growth or addressing societal concerns such as climate change. Against this backdrop, researchers advocate for active government intervention in shaping technological development, a role that governments have increasingly assumed in recent decades. Yet, it remains unclear where exactly public funds are channeled, and whether this is in line with wider policy objectives. This thesis offers empirical evidence on the allocation of public funding in Sweden between 1970-2021. To this end, a comprehensive database over public innovation funding is created, where individual public funding projects are directly linked to innovation outputs. The database has been used to investigate the quantitative dimension, direction, network additionality, and output additionality of public funding. Sweden is selected as the research subject, since it was among the first countries to actively promote applied research, ranks among the most innovative countries today, and is considered a pioneer in sustainable development. The thesis highlights the importance of public support for innovation development. It shows that public funding is associated with types of innovation projects that are typically less likely to receive private funding, particularly innovations developed by small firms, radical innovation, and green innovation. Innovations involving innovation agencies are more likely to bring together diverse sets of collaborators, which in turn are associated with the development of radical innovations. Finally, public funding shows signs of output additionality, as approved public funding projects are nearly twice as likely to generate significant innovation outputs.			
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1970-2021.

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A doctoral thesis at a university in Sweden takes either the form of a single, cohesive research study (monograph) or a summary of research papers (compilation thesis), which the doctoral student has written alone or together with one or several other author(s).

In the latter case the thesis consists of two parts. An introductory text puts the research work into context and summarizes the main points of the papers. Then, the research publications themselves are reproduced, together with a description of the individual contributions of the authors. The research papers may either have been already published or are manuscripts at various stages (in press, submitted, or in draft).

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List of publications

This thesis is based on the following publications, referred to by their Roman numerals:

- I **Shifting priorities – Funding innovation in times of climate crisis and economic turmoil**
J. Fink

- II **Picking winners and directions? Public innovation funding in Sweden, 1970-2021.**
J. Fink, J. Taalbi

- III **Quantifying the brokerage power of Swedish innovation agencies, 1970–2021.**
J. Fink

- IV **The effect of public funding on Swedish innovation, 1970–2001.**
J. Fink, S. Torregrosa-Hetland

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Growing up with two parents in academia I used to say: "I would never want to do this job!" Why would anyone want to work on evenings and weekends voluntarily? However, 20 years later I apparently no longer held on to these principles and decided to apply for a PhD.

Anyone who has or is currently working on their PhD can probably relate to the constant ups and downs during the writing process, accompanied by self-doubts, and questioning why you chose to torture yourself this way. However, the positive atmosphere at the department and the company made up for the hardship.

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Shaping innovation

1 Introduction

1.1 Funding innovation

The importance of innovation and technical change for economic growth has been subject for discussion ever since the establishment of economics in the late 18th century.¹ Rapid technological progress and economic growth over the past two centuries have contributed to an unprecedented increase in wealth and living standards (Mokyr, 1992). Innovations such as steam engines, the internal combustion engine, electricity, and microprocessors play a crucial role in this development as they transformed our modes of production, transportation, and communication (Kuznets, 1980; Aghion et al., 1998). Continued technological progress remains therefore on the top of public agendas.

Nonetheless, previous research suggests that firms will usually underinvest in research and development (R&D) as they do not take societal benefits arising from knowledge spillovers into account (Nelson, 1959; Arrow, 1962). Thus, there is a need for governments to provide additional incentives for innovation development to achieve the societal desired level of technological progress. More recent work also calls for governments to take a more active role in innovation development, by creating markets for new technologies (Mazzucato, 2013; Wang et al., 2024).

Furthermore, the spread of modern technology resulted in a massive increase in population and natural resource consumption. Importantly, fossil fuel combustion for energy use is the main contributor of human made climate change (IPCC, 2018; Akpan and Akpan, 2012). Nevertheless, individual economic actors rarely take negative environmental externalities into account, overstraining the environmental and natural resources (Baumol, 1972; Bithas, 2011). In response to this, calls for greater regulation of technological development and for governments to *direct* technological development towards a more sustainable path are growing louder.

Several policy tools exist that allow governments to guide and direct technological change. One of them is the provision of public innovation funding, which can generally promote R&D activity but also direct it towards green innovation²

¹Smith (1776, p. 38) discusses the positive impact of the introduction of machines on labor productivity. Differences in technology, embedded in the capital stock, are also central to the trade model outlined by Ricardo (1821).

²Green innovation refers in this thesis to technologies targeted towards sustainable resource use, reduction of environmental pollution, and energy technology.

(Nemet, 2009; Mazzucato, 2013). For the latter, public funding should be coupled with clearly outlined missions that direct public resources towards projects in line with environmental targets (Wanzenböck et al., 2020; Aalbers et al., 2013; Akpan and Akpan, 2012; Westmore and Meadmore, 2022).

However, several questions regarding the impact of public funding on innovation activity remain unclear. 1. Does public funding create something that would not exist in its absence? 2. Is public funding directed towards the most promising research projects? 3. Does public funding promote green innovation?

Question 1 relates to the literature on public funding *additionality* (Howell, 2017; Lerner, 1999). Public funding might be considered efficient if it creates additional innovation outputs, draws in private funding, or changes innovation behavior. Studies assessing public funding additionality have specific data requirements. The main challenge being the construction of robust control groups (Falk, 2007; Zúñiga-Vicente et al., 2014).

Closely connected to this, Question 2 is related to the literature on *picking winners*. Critics suggest that the government lacks this ability and wastes resources on meaningless projects (Helm, 2010; Lerner, 2009; McKenzie, 2017), while proponents point to higher public funding access among award winning innovation, and groundbreaking public projects such as the moon landing (Block and Keller, 2009; Bloch and Graversen, 2012; Mazzucato, 2011).

Regarding Question 3 empirical evidence suggests that public funding is more frequently directed towards green innovation projects (Owen et al., 2018; Jugend et al., 2020). However, Pless et al. (2020) outline the need for a long-term database encompassing both innovation inputs (public funding) and innovation outputs, with detailed descriptions to determine the direction of public innovation funding. A few studies use databases containing actual innovation outputs.³ However, there exists no study that directly links single public funding projects to innovation outputs.

1.2 Scope of the thesis

This thesis lies on the intersection of economic history and innovation policy. Its aim is to contribute to discussions on public funding, particularly the direction of technological development towards green and radical innovation, networking behavior, and the creation of additional innovation outputs during the third industrial revolution. To this end, a comprehensive database over public in-

³Exceptions include studies using community innovation surveys (Hottenrott and Richstein, 2020; Bruno et al., 2026), award-winning innovations in the US, (Block and Keller, 2009, 2015) and a recent study investigates the role of public funding on innovation output in Finland (van der Have and Deschryvere, 2026).

novation funding in the long run is created where individual public funding projects are linked to innovation outputs (1970-2021). The lack of a comparable data basis has been identified as impeding advancements in discussions on innovation policy (Pless et al., 2020).

While there exist a multitude of policy instruments to steer and promote innovation activity, this thesis focuses specifically on public funding for applied research. Large fractions of existing research focus either on macro-level indicators or individual policies, neither of which is suitable for analyzing the impact of public policy on individual innovations in a long-term or historic perspective (Edler et al., 2016; Janger et al., 2017; Torregrosa-Hetland et al., 2019).

Sweden is selected as the research subject since it was among the first countries to adopt a second-generation innovation agency (Weinberger, 1997; Eklund, 2007; Arnold and Barker, 2022),⁴ enforce comprehensive environmental protection laws (Larsson Heidenblad, 2021; Shmelev and Speck, 2018; Hysing, 2014; OECD, 2025), and ranks today among the most innovative countries in the world (Dutta et al., 2023; Eurostat, 2025).⁵ Furthermore, Sweden is particularly interesting to study from an economic historical perspective, since its position as an innovation leader is a recent development. Historically, Sweden has been dependent on technology imports, and as recent as 20 years ago foremost developed low- and medium-technologies despite high R&D investments (Heckscher, 1932; Edquist and McKelvey, 1998; Schön, 2012, p. 127).

Collaboration has become increasingly important for innovation development over recent decades (Burt, 1992; Acemoglu et al., 2016). Also in this context Sweden is interesting to study, since the first Swedish innovation agency⁶ has presented itself as a network broker, a highly connected and trusted entity that acts as a go-between for innovative companies and organizations (Weinberger, 1997; Lomas, 2007). The analysis is guided by four research questions, which are addressed in the four papers presented in Table 1.

1. To what extent is public funding associated with directing technological development towards green innovation? (Paper I and Paper II)
2. Is public funding directed towards projects that are less likely to obtain funding? (Paper II and Paper III)
3. To what extent do innovation agencies occupy brokerage positions within innovation networks? (Paper III)

⁴Second-generation innovation agencies are among others characterized by a shift of public support towards applied research (Weinberger, 1997).

⁵Sweden ranks at the top of the Global Innovation Index, and the European Innovation Scoreboard (Dutta et al., 2023; Eurostat, 2025).

⁶The first Swedish innovation agency STU operated from 1968-1991.

4. Does public funding create additional innovation outputs? (Paper IV)

Table 1: Structure of the dissertation

Paper	Description	Method	Data	Author	RQ
I	Shifting priorities – Funding innovation in times of climate crisis and economic turmoil How has the direction of public funding changed? Has funding shifted towards green innovation? Are economic crises associated with changes in funding priorities?	Interrupted time series, Content analysis	PFD, SWINNO, Regulation letters		Q1
II	Picking winners and directions? Public innovation funding in Sweden, 1970–2021. Which innovations are most likely to receive public funding? Is public funding associated with radical and renewable energy innovations?	Logistic regression	PFD, SWINNO		Q1; Q2
III	Quantifying the brokerage power of Swedish innovation agencies, 1970–2021. What brokerage roles do innovation agencies occupy within innovation networks? Do they connect otherwise disconnected actors?	Network analysis, Probabilistic regression	PFD, SWINNO, Collaboration data		Q2; Q3
IV	The effect of public funding on Swedish innovation, 1970–2001. Who applies for public funding? Does public funding generate additional innovation outputs and radical innovations?	Matching, Logistic regression	PFD, SWINNO, Rejected projects		Q4

 Single-authored
  Co-authored
 PFD: Public Funding Database

1.3 Contributions

The creation of a novel database that directly links public funding inputs to outputs is among the main contributions of the thesis. Data on significant Swedish innovations has been obtained from the SWINNO database (Sjöo et al., 2014; Kander et al., 2019). Information on innovations is sourced from journal articles, based on the literature based innovation output (LBIO) method (see Section 4.1

and Kleinknecht and Bain (1993)). The trade journal articles contain information that allow detailed descriptions of each innovation and key information, including innovating firms, year of commercialization, collaborating firms, and product groups.

While SWINNO contains some information on funding sources,⁷ there was no comprehensive database covering public innovation funding in Sweden prior to this thesis project, or at least none that covered the entirety of the observation period. A previous study by Torregrosa-Hetland et al. (2019) indicates that public funding data in SWINNO is incomplete, underestimating public funding by approximately a factor of four.⁸

To fill in this gap, public funding data has been collected from seven different data sources, out of which two were not available in digital form. Data from 1968-1978 was digitized manually by the author. This work took approximately 1.5 years of full-time work.⁹

Manual work did not end there. The creation of the linked dataset also required the development of a reproducible linking approach. Due to fine nuances in descriptions of innovations and public funding projects, attempts to fully automatize the linking approach proved unsuccessful. In consequence, final linking decisions were conducted manually.¹⁰ The results of the linking process suggest that relying solely on trade journal sources substantially underestimates the extent of public funding, by a factor of four, in line with previous estimations by Torregrosa-Hetland et al. (2019). This indicates that public funding plays a considerably larger role in supporting innovation projects in Sweden than previously recognized.

A special feature of the approach presented in this thesis is the direct link between individual public funding projects and innovation outputs. Previous studies do not offer such fine-grained linkages between public funding and individual innovation outputs since they consider an innovation to be developed with public funding if the innovating firm(s) received any public funding, independent of its exact purpose (Block and Keller, 2009; van der Have and Deschryvere, 2026). The combined database has been used to analyze the direction and performance of public funding in terms of *directionality*, *picking*

⁷Information on funding sources is available for 9% of observations. 6% of innovations are reported to have obtained public funding.

⁸Torregrosa-Hetland et al. (2019) conducted a survey among innovative firms in the Swedish ICT sector, in which 68% of the firms reported that they received some public funding, compared to 15% in SWINNO.

⁹I am very grateful for the assistance of Jakob Nyqvist in taking photos of the archival sources, which saved me numerous trips to Stockholm. Moreover, I want to thank Philip Jonas Kreutzer for trying to automatize the digitization process. These were unfortunately not successful due to inconsistent formatting of the data sources.

¹⁰For more details see Sections 4.2 and 6.

winners, output-, and network additionality.

Paper I and II investigate the long-term direction of public funding. While this has been done in multiple previous studies, the datasets usually consist of aggregate R&D data, limiting possibilities to investigate the specific purpose of innovation projects. Moreover, data used in previous studies seldom covers multiple decades. This limits possibilities to observe long-term trends and shifts in the direction of public funding (Mazzucato, 2015; Cecere et al., 2020).

Further, the thesis provides some empirical findings towards the debate whether public agencies are able to identify the most promising projects or *picking winners*. The results of Paper II suggest that public funding strongly correlated with highly significant innovation. This result is robust to alternative measures of innovation significance.

Paper III delves into the literature on network additionality and knowledge brokerage. While the study design is not suited for detecting causal effects, the results reveal a positive correlation between public funding access and the creation of diverse collaborator pairs. These are considered as most likely to produce radical innovation (Filippetti and Zinilli, 2023; Kang and Hwang, 2016; Burt, 1992). Moreover, Paper III is to my best knowledge the first to quantitatively estimate the brokerage power of a public funding innovation agency.¹¹

The final paper of the thesis takes advantage of the availability of data on rejected public funding applications before 2002 to estimate output additionality. Rejected applications are used to construct a robust control group, which has been done in few previous studies (see Czarnitzki and Hussinger (2018)). This paper is to the best of my knowledge the only study that directly links individual public funding projects to innovation outputs collected with the literature based innovation output method (LBIO).¹²

1.4 Limitations

This thesis provides extensive evidence on long-term trends and correlations of public funding allocation. Nevertheless, only Paper IV is attempting to isolate causal effects. While this does not devalue the importance of the presented findings, it should be kept in mind when interpreting the findings of this thesis. For example, correlations between two variables (indicated by a positive coefficient in a regression table) should not be interpreted as deterministic effects.

¹¹Paper III even estimates the brokerage power of four different innovation agencies.

¹²van der Have and Deschryvere (2026) also link LBIO based innovation outputs to public funding. However, they do not capture links between individual projects and innovation outputs. Rather they focus on general access to public funding.

The combined database has so far not been linked to alternative forms of R&D funding. This includes funds from the firms' own capital but also venture capital and non-Swedish public funding, such as innovation funding from the European Union (EU). Therefore, the database can in its current form not be used to study questions related to input additionality, whether public funding *crowds out* private R&D investments (see Section 2.6).

Moreover, firm information in the database is limited to those firms and organizations which developed significant innovation outputs and/or applied for public funding. Therefore, the papers included in this thesis cannot test for differences between innovative firms and others, or for selection into applying for public funding (Paper IV).

While there exists an established literature on general Swedish innovation policy and funding for basic research (Annerstedt, 1972; Schilling, 2005; Edquist, 2019; Lundin and Gribbe, 2023), this thesis only aims to contribute to the discussions directly surrounding public funding for applied research (Weinberger, 1997; Sandström et al., 2018; Arnold and Barker, 2022).

Apart from Paper I,¹³ this thesis considers actual innovations as the sole measure of innovation outputs. This limits comparability of the here presented results to previous studies which most frequently rely on innovation proxies such as R&D funding and patents.

2 Theoretical considerations and previous research

2.1 Central terms and definitions

This subsection aims to define central terms such as innovation and public funding to avoid potential misunderstandings in the remainder of the thesis.

Defining the term innovation is not trivial as it has been in use since the Middle Ages and has become a buzz word in recent years (Godin, 2017).

Innovation is everywhere. In the world of goods (technology) certainly, but also in the realm of words: innovation is discussed in the scientific and technical literature, in social sciences like history, sociology, management and economics, and in the humanities and arts. Innovation is also a central idea in the popular imaginary, in the media, in public policy and is part of everybody's vocabulary. (Godin, 2017, p. 5)

This thesis follows the definition from the Oslo Manual:

¹³Paper I considers both public R&D funding, as well as actual innovations.

"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD and Eurostat, 2005, p. 46)

Special emphasis is placed on the fact that innovations are put to actual economic use. This was already highlighted by Joseph Schumpeter more than 100 years ago. *"As long as they are not carried into practice, inventions are economically irrelevant."* (Schumpeter, 1911, p. 72)

Innovation studies became closely intertwined with the studies of technological change during the middle of the 20th century. This still shapes the common perspective of innovation today, as the term innovation is still closely associated with technical or technological innovation (Godin, 2017). Nonetheless, the term has been broadened over the last decades. The Oslo Manual identifies four different main categories: Product, process, marketing, and organizational innovation (OECD and Eurostat, 2005, p. 47). Thus, innovation might be neither physical nor technical. However, these types are not captured in SWINNO, and hence not part of the present analysis.

Furthermore, innovation has a collaborative dimension. Chaminade et al. (2018, p. 1) characterize innovation activity as *"an interactive process where different kinds of knowledge are combined through communication within and across organizational borders."* This view differs from early innovation research which focused on the work of individual inventors (Schumpeter, 1911; Godin, 2017).

Another important factor in the innovation definition is novelty. The OECD and Eurostat (2005, p. 57-58) distinguishes between three different levels of novelty: new to the firm, new to the market, and new to the world. Definitions of *new to the firm* and *new to the world*, referring to an innovation that has not been implemented within the firm or the world previously. The term *new to the market* is more ambiguous, it can refer to a sector, industry, or a geographic unit. For example it may refer to an innovation that has not been previously used within a certain country.

Further this thesis distinguishes between innovation of different levels of significance. *Incremental* innovation refer to those innovations with a low degree of novelty, such as modified versions of existing products (Ali, 1994).

Innovations not falling into this category are referred to under various terms in innovation literature, and distinctions between them are somewhat floating. Some authors refer to these innovations as *non-incremental* (Nemet, 2009), *pioneering* (Ali, 1994), others as *radical* (McDermott and O'Connor, 2002). In this thesis the preferred terms are *highly significant* or *radical* innovations. These are characterized by being new to the world or firm, and cited in multiple journal articles. A detailed definition is provided in the Appendix 6.

In this thesis public funding refers to all funding provided by public authorities for innovation development. Since public funding is defined here as being specifically targeted to innovation activity, the terms public funding and public innovation funding are used interchangeably unless specified otherwise. Innovation development refers to every stage of the innovation process. This includes the initial idea, basic research, development, demonstration, market formation, commercialization, and diffusion (see Section 2.2).

Within the discussion of directionality it is important to distinguish between renewable and non-renewable energy sources. This thesis follows the definition by Panwar et al. (2011):

"Renewable energy sources are those resources which can be used to produce energy again and again, e.g. solar energy, wind energy, biomass energy, geothermal energy, etc. and are also often called alternative sources of energy. [They] have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases."
(Panwar et al., 2011, p. 1514)

Therefore, biomass, geothermal, hydro, solar, and wind energy are classified as renewable sources, while fossil, nuclear, and waste are classified as non-renewable sources.

2.2 From the linear model to innovation systems

In a historic perspective the innovation process has long been portrayed as following a linear path, and being deterministic in nature (Price and Bass, 1969; Kline, 1985). The most popular depiction of this is the linear model of innovation, according to which the innovation process consists of four clearly delineated stages (see Figure 1). The research stage is followed by development, demonstration, and diffusion. Under this assumption if innovation inputs such as public funding are entered into the chain, they will simply move through the four stages and finally translate into innovation outputs.

Figure 1: Linear innovation process

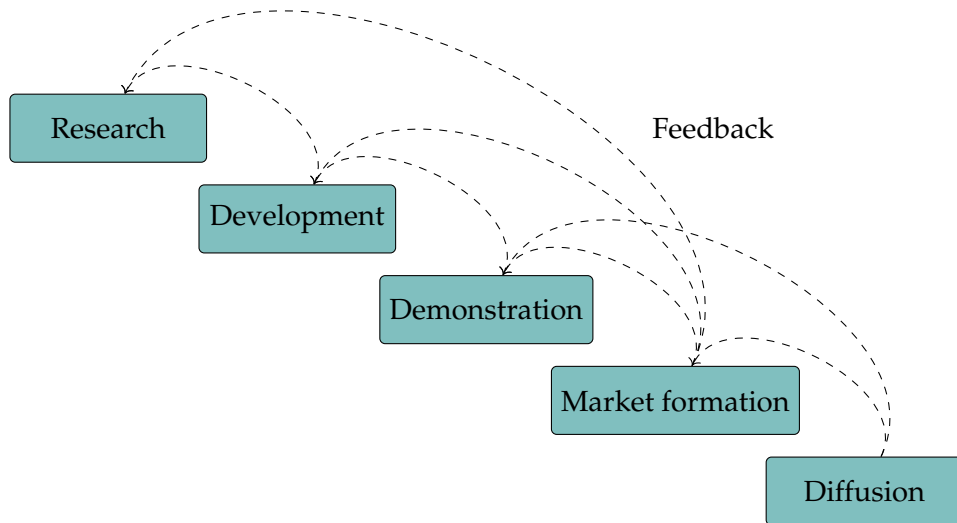


Source: Adapted from Kline (1985)

However, this simplistic model did not align with empirical evidence which highlights the importance of feedback during later development stages (Price and Bass, 1969). For example, if demonstration teams identify bugs in the

prototype, research and development teams would take up their work again to refine the final product. In response, researchers developed alternatives to the linear model, such as the chain-linked innovation model (Kline, 1985). As depicted in Figure 2, the different stages of the innovation process are no longer restricted to a clear temporal order. Rather, later stages provide feedback to earlier stages that resume their work on refining the innovation if necessary.

Figure 2: Chain-linked innovation model



Source: Adapted from Gallagher et al. (2012)

The linear model was fully abandoned with the emergence of the national innovation systems thinking in the late 1980s (Freeman, 1987; Lundvall et al., 1992). This literature is concerned with economic performance on the national level in the context of competitiveness and economic growth. The term national innovation systems was first mentioned in articles by Freeman (1982) and Lundvall (1985), and developed in greater detail in following publications (Lundvall et al., 1988, 1992; Nelson and Rosenberg, 1993; Freeman, 1987). The field is highly interdisciplinary and combines concepts from innovation studies, long-term economic growth theory, evolutionary theory, network theory, and geography of knowledge (Chaminade et al., 2018, p. 31). Lundvall et al. (2009) define the national innovation system as an:

"open, evolving and complex system that encompasses relationships within and between organisations, institutions and socioeconomic structures which determine the rate and direction of innovation and competence"

building emanating from processes of science based and experience based learning.” (Lundvall et al., 2009, p. 7)

This definition highlights several crucial aspects of the innovation system. Namely collaboration between different actors within the system, evolution of the innovation system across time and the combination of science- and experience-based learning. The innovation system literature emphasizes the importance of knowledge exchange and collaboration in the innovation process, taking inspiration from network studies and social psychology (Freeman, 1987). Furthermore, this literature highlights the importance of adaptability and successful diffusion of novel technologies. Lundvall et al. (1988) notes that not always the countries developing radical or path-breaking innovations are the ones that benefit the most from them. Rather, those countries that are able to adopt new technologies effectively will be the main beneficiaries.

While the concept of innovation systems was first developed on the national level, it has been adapted to the regional (Asheim and Gertler, 2006), sectoral (Breschi and Malerba, 2013), technological (Gallagher et al., 2012; Bergek, 2019), and corporal level (Granstrand, 2000). The national perspective of the innovation system is central to this thesis, since it focuses on public innovation funding in Sweden. However, a growing literature discusses whether defining innovation systems on the national level remains appropriate in face of increasing regional and global integration of the innovation process (Asheim and Gertler, 2006; Asheim et al., 2011). Since Sweden joined the EU in 1995, it holds no longer full sovereignty over its innovation policy making. Thus, a regional innovation systems perspective needs to be considered during the second half of the observation period.

2.3 The rationale behind public funding

Public funding falls under the umbrella of industrial policies, which can be defined as:

“[T]hose government policies that explicitly target the transformation of the structure of economic activity in pursuit of some public goal. [...] Industrial policies can take various forms but always create incentives for private-sector actors – firms, innovators, investors – to acts in ways that are consistent with the intended direction of structural change.” (Juhász et al., 2024, p. 216)

This definition is open-ended, and encompasses aside from public funding also other kinds of subsidies, public-private collaborations, and the provision of public goods (Juhász et al., 2024).

The rationale behind public intervention in innovation activity is closely related to the theory on market failure (Arrow, 1962; Nelson, 1959).¹⁴ When private companies make R&D investment decisions, they focus on generating maximum gains for themselves in the short run. The innovation process is characterized by fundamental uncertainty and novel technologies may take several years until reaching maturity during which they do not create revenues for the company (Alchian, 1950; Kline, 1985). The failure of a single innovation might result in the bankruptcy of a private company. Therefore, firms try to minimize the inherent risks of the innovation process (Hall and Lerner, 2010; Warwick and Nolan, 2014). However, what is ideal for an individual company is not necessarily best for society as a whole. Proponents of public funding argue that individual actors do not internalize positive externalities of innovation activity. This problem is amplified in the energy sector, where extended development time and the need for complementary infrastructure raises obstacles for individual firms (Fouquet and Pearson, 2012; Gallagher et al., 2012; Mazzucato and Semieniuk, 2018). Thus, relying on private investment alone might result in an underinvestment in R&D activity.

By contrast, it has been argued that public actors play an important role in developing high-risk technologies, requiring long-term funding (Fouquet and Pearson, 2012; Mazzucato and Semieniuk, 2017, 2018; Wang et al., 2024). Governments have access to far greater funds than most companies allowing them to provide long-term finance and constructing complementary infrastructure without running the risk of bankruptcy in case of a failed innovation.

Moreover, public and private actors differ in terms of ideological motivation (Mazzucato, 2011; Mazzucato and Semieniuk, 2018). Public actors are to a higher extent driven by political instead of pure economic considerations when allocating public funding. Thus, public actors are found to be more willing to invest in immature technologies as long as they are aligned with their long-term vision for technological development. This is of particular importance for the development of green technology (Acemoglu et al., 2016, 2023; Aghion et al., 2019).

2.4 Directing technological development

The need for governments to direct technical change were already voiced by Bush (1945) in the mid-1940s.

Research within the Government represents an important part of our total

¹⁴Juhász et al. (2024) also discusses coordination failures and activity specific public funding inputs as motivations for public intervention in economic activity. Nevertheless, these are only of minor importance for public funding.

research activity and needs to be strengthened and expanded after the war. Such expansion should be directed to fields of inquiry and service which are of public importance and are not adequately carried on by private organizations. (Bush, 1945, p. 19)¹⁵

Based on this line of thinking two streams of literature have evolved. The first one focuses on promoting radical innovation. After the groundbreaking publication of Solow (1956) the connection between technological progress and economic growth became widely recognized (Dosi, 1982; Nemet, 2009). However, it also ignited a debate whether the direction of technical change was driven rather by technological progress (technology-push) or market demand (demand-pull).

Demand-pull incentives refer to policies that increase the payoff of successful innovations, including government procurement, intellectual property protection, tax credits, regulatory standards, and taxation of competing technologies (Nemet, 2009). In contrast, technology-push instruments allow governments to directly promote innovation activity. This encompasses public support for R&D, both directly and through tax incentives (Dosi, 1982).

It has been widely recognized that push- and pull-explanations are not mutually exclusive, as innovation activity requires both the creation of technological capabilities, as well as the creation of markets for the successful commercialization of new products and processes (Kleinknecht and Verspagen, 1990; Arthur, 2007). However, findings by Nemet (2009) indicate that technology-push incentives including public R&D funding are more conducive in promoting highly significant innovation.¹⁶

The second stream of literature focuses on directing technological development towards green innovation. This has become the dominant definition of direction over recent decades. This thesis will follow this definition, if not specified otherwise.

There are multiple tools allowing governments to steer innovation activity (Kaijser and Kander, 2013). On the one hand, governments can use tools like regulation, prohibitions, and penalties to force companies to adapt and for example abandon environmentally harmful practices. On the other hand, subsidies, tax incentives, and public funding, which drive transformations by creating economic opportunities.

Several studies focus on the role of carbon prices in directing innovation (particularly within the energy sector) towards green technologies. Popp (2002) uses

¹⁵Interesting about this statement is the link to the market-failure hypothesis, later formalized by Nelson (1959) and Arrow (1962).

¹⁶Nemet (2009) investigates patent activity in the US wind power industry and its response to demand-pull policies in the 1980s. They also highlight the risk of inconsistent policy schemes on hampering the success of demand-pull approaches (see (Hansen et al., 2018)).

US patent data (1970-1994) to estimate the effect of energy prices on the production of energy efficient innovations. The author identifies, both energy prices and existing knowledge stock are main determinants. Noailly and Smeets (2015) investigate the direction of technological innovation in electricity generation based on patent data (1978-2006) from 5,471 European firms. According to their findings, the shift towards green innovation is driven by small and specialized rather than large incumbent firms. Aghion et al. (2016) use patent data (1965-2005) from 3,412 firms and individuals to estimate the impact of carbon prices on direction of technological change. Similar to Popp (2002), both increases in fuel prices and the existing stock of knowledge promote green innovation.

The *mission innovation* literature assigns governments the autonomy to steer economic activity towards societal objectives (Mazzucato, 2013; Aiginger and Rodrik, 2020; Wanzenböck et al., 2020). While this literature endorses public involvement in innovation activity, it challenges the market failure perspective, arguing that the role of public actors should extend beyond correcting market failures to encompass the shaping and creation of markets (Mazzucato, 2016; Wang et al., 2024).¹⁷

While recent discussion around mission-oriented innovation policy is generally focused on the transition towards sustainable development, the most prominent examples of historical missions are related to military and aerospace technology (Mazzucato, 2013; Wang et al., 2024). In particular, the Apollo program and the Manhattan project, where governments brought together hundreds of thousands of individuals with a nearly unlimited budget to achieve a clearly outlined target (Gisler and Sornette, 2009).

The formulation of public funding targets can be an important tool in directing public innovation funding, as they signal to both applicant firms and funding organization which type of technological development are most desirable (Mazzucato, 2013, 2016). These targets should provide a clear direction for economic development in the long run. For example, a commitment to provide governmental support for energy-saving technologies for the upcoming 20 years. However, it should be considered that single technologies are insufficient to address the current crisis. Governments should therefore opt for supporting the development of multiple technologies rather than focusing on a single technology, which is in line with the theory on risk diversification (Koumou, 2020).

Important here is to highlight differences in the definition of missions between the mission-oriented innovation policy and the literature on socio-technical transitions, that are often used interchangeably in innovation literature (Avdeitchikova

¹⁷This perspective is inspired by the discussion of Polanyi (1944) on the role of government in creating capitalist markets.

et al., 2024). While both evolve around directing innovation activity towards societal challenges, the mission-oriented innovation literature places missions, referring to concrete, measurable, and time-bound targets, as the main tool to direct technical change. In contrast, the transitions literature focus on the systemic interplay between innovation development, diffusion, demand creation, and actor strategies. This implies that attempts to redirect innovation activity require a broad transformation of the existing innovation system, rather than fitting within the existing one. This thesis follows the definition from the mission-innovation literature.

2.5 Picking winners and rent-seeking

Despite the advantages of public funding outlined in the previous section, there exists a substantial literature that opposes public intervention into economic activity. Investments of public actors tend to be scrutinized more closely than private investments, since failed public investment is associated with a waste of tax money (Meckling et al., 2022).

The first point of critique is directed towards governments' perceived inability to *pick the winners* or select the most promising projects. Since governments lack information on firms internal affairs, proponents of this view argue that publicly funded projects are more likely to fail compared to privately funded projects (Pack and Saggi, 2006; Helm, 2010; Lerner, 2009; McKenzie, 2017).

The second point of critique concerns the creation of incentives for *rent-seeking* behavior (Krueger, 1974). Juhász et al. (2024) link this argument to the nature of industrial policy. Since governments decide to either fund A or B, interest groups will try to influence policy makers towards their product even if this is not in line with societal interests. This strand of the literature emphasizes the tendency of firms to maximize their short-term profits, by obtaining as much public funding as possible while delivering only minimal results (Kealey, 2001; David, 1997). According to Buchanan et al. (2003), this also one of the main risks associated with sector-based innovation policies.

The mission-innovation literature proposes that governments should focus on *picking the willing*, thus firms that are willing to align with wider innovation policy targets (Mazzucato, 2013; Hekkert et al., 2020). Central to this approach is the creation of new markets through the direction of innovation activity. Governments should provide clear targets and provide support for companies that conduct research activity in line with these.

A related but slightly different position is the *letting losers go* perspective. While governments cannot pick winners due to information asymmetry, they should focus on identifying failing projects and discontinue these in a timely manner (Rodrik, 2007; Juhász et al., 2024). Hausmann and Rodrik (2003) propose a carrot

and stick approach: governments should support firms' innovation activity, however, this support should be conditional and discontinued in case of poor firm performance. If all public funding were successful this might indicate that governments are too conservative in their funding decisions and merely support for projects characterized by low risk and modest expected returns (Rodrik, 2007, p. 107).

Conditions for public funding eligibility are discussed in greater detail by Mazzucato and Rodrik (2026). Public resources are typically directed towards specific types of firms, targeting for example firms with limited access to alternative funding or those located in peripheral regions. Moreover, public funding agencies increasingly apply measurable performance criteria. These may include patent acquisition, scientific publications, improvements in technical performance, employment growth, and, where programs are directed towards green innovation, outcomes such as improved energy efficiency and compliance with environmental protection regulations.

2.6 Evaluating public funding

After outlining the importance of public funding, possibilities to direct innovation development, and addressing the most commonly voiced critiques, the question remains how public policy can be evaluated. This is the central question discussed in the additionality literature.

The additionality literature is centered around the idea that public policy is effective if it creates something that would not exist in its absence. Three types of additionality are distinguished (Falk, 2007). Input additionality addresses the question whether public investments incentivize additional private investments or rather replace them (Bloch and Graversen, 2012; Zúñiga-Vicente et al., 2014). Output additionality is concerned with the question whether providing public funds generates additional outputs, such as innovations and patents (Lerner, 1999; Howell, 2017). Finally, behavioral additionality arises if firms receiving public support change their innovation behavior. According to Cameron et al. (2005), behavioral additionality might take place even if neither evidence for input nor output additionality can be detected. Network additionality falls into the latter category. It is particularly concerned with the question whether public policy affects collaboration behavior.

The literature on input additionality is the most developed among these three streams.¹⁸ Since information on private funding is unfortunately not available,

¹⁸Several studies conducted in the last two decades have found no *crowding-out* effects, and actually *crowding-in* in some contexts. The latter refers to cases in which public funding triggered additional private funding (Görg and Strobl, 2007; González and Pazó, 2008; Aerts and Schmidt, 2008; Hussinger, 2008; Bloch and Graversen, 2012). However, other studies show the opposite.

this thesis cannot contribute to the discussion surrounding input additionality. Instead, it addresses the less developed literature on output and network additionality.

Output additionality

A large variety of studies investigates output additionality, since all kinds of firm and innovation outcomes have been considered (Falk, 2007). While some studies focus on firm outcomes, including sales, employment, and profits (Lerner, 1999; Wallsten, 2000), other studies have estimated output additionality based on patents, a proxy for innovation outputs (Czarnitzki and Licht, 2006; Czarnitzki et al., 2007; Plank and Doblinger, 2018; Widmann, 2024). Finally, a few studies consider actual innovation outputs. While these studies originate from a wide variety of different countries and different time periods, the results are overwhelmingly positive.

Hewitt-Dundas and Roper (2010) found positive effects of public support in the share of sales corresponding to new products, in a study on manufacturing firms in Ireland and Northern Ireland (1994-2004). Using a similar approach, comparable results are found in Prencipe et al. (2024), who studied Spanish firms (2009-2014). Bérubé and Mohnen (2009) analyze the case of Canada in 2002-2004, finding that firms that benefited from R&D grants introduced more new products, including more world-first innovations.¹⁹ Foreman-Peck (2013) studies UK manufacturing and service firms in the same period, showing that publicly supported firms were more likely to introduce new products or processes. In the United States, Smith (2020) found that firms granted funding by the “Advanced Technology Program” between 1998-2000 announced more new products in the following years (2001-2014). Similarly, van der Have and Deschryvere (2026) study R&D grants in Finland (1997-2018), showing that publicly supported firms were much more likely to introduce innovations. This last article is of special interest since it is the sole previous study identifying innovation through a literature based innovation outputs (LBIO) approach (see Section 4.1).

Network additionality

Network additionality is concerned with the question whether public policy affects collaboration behavior. The majority of previous studies has focused

There exists no evidence of input additionality or even evidence for high substitutability between both types of funding (Marino et al., 2016; Lee, 2011; Zúñiga-Vicente et al., 2014).

¹⁹These firms are compared with other firms receiving no grants, but both groups get support in the form of R&D tax credits.

on organizational learning in firms and innovative behaviors among SMEs (Clarysse et al., 2009; Berrutti and Bianchi, 2020; Bergman et al., 2010; Caloffi et al., 2018).

Collaborator pairs with heterogeneous or complementary characteristics have been linked to radical innovation. The latter are of special interest for policy makers through their impact on economic growth and social welfare (Filippetti and Zinilli, 2023; Kang and Hwang, 2016; Burt, 1992). Within diverse collaborations, participants must balance the collaborating firms' visions of the final product and the combinations of their complementary skills and characteristics (Burt, 1992).

A few recent studies investigate innovation networks created through public funding provision. Kang and Hwang (2016) focus specifically on the innovation network created by EU funding for renewable energy technologies in 2003-2013. The innovation network is characterized by local clusters that become increasingly integrated over time. However, the structure of the network is deemed as ineffective at connecting firms engaging in complementary activities, namely producers and users of knowledge. To address these inefficiencies, the authors call for knowledge brokers to connect firms with complementary skills. Min et al. (2020) evaluate the impact of public funding on innovation efficiency in South Korea, focusing on drivers of inter-regional disparities in innovation efficiency. To maximize the potential of regional innovation projects, the authors recommend the simultaneous adoption of policies promoting public R&D expenditure and network building.

Cooperation additionality arising from the provision of public R&D funding is studied by Wanzenböck et al. (2013).²⁰ Based on the study's findings, cooperation additionality is lower among highly innovative firms, established in the field, as they are most likely already connected with relevant partners. In consequence, public funding is best channeled towards less innovation intensive, newly established firms.

3 The Swedish context

This section introduces readers to the specifics of the Swedish context that are little known outside the country, or in case of the public funding system even to the majority within it. Particularly, it discusses the emergence of public innovation funding in the light of wider socio-economic developments in Sweden, such as the emergence of the Swedish model.

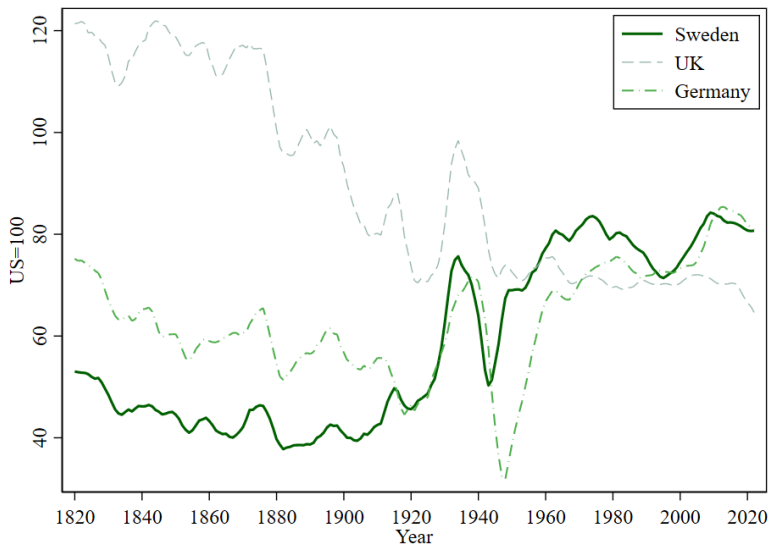
²⁰Participating firms are asked whether they created contact with new partners due to the provision of public R&D support programs, or when collaboration is continued after the publicly funded projects is completed.

3.1 Technological and socio-economic development since industrialization

The second industrial revolution and the emergence of the Swedish welfare state

While we think today of Sweden as one of the most advanced and egalitarian countries in the world, it was perceived as poor and backwards in comparison to leading economies in Western Europe and North America just 100 years ago (Lundberg, 1985). US GDP per capita is compared to that of Sweden, the UK, and Germany between 1820 and 2020 in Figure 3. Until the 1920s, Sweden lagged behind the other three countries in terms of economic output per capita. In comparison to the US, GDP per capita remained at approximately 50% throughout the 19th century. In 1900, incomes in Germany and the UK were 20% and 80% higher, respectively. Sweden caught up to income levels in Germany and the UK only after World War I and World War II, respectively.

Figure 3: Comparison of GDP per capita to the US, 1820-2020 (5-year moving average)



Source: Bolt and Van Zanden (2025) Notes: GDP estimates are presented relative to the US (US=100).

The primary sector dominated economic activity for most of Swedish history. It only lost its dominant position in terms of value added and the number of employees to manufacturing in 1895 and 1934, respectively (Edvinsson,

2005). The majority of labor within the primary sector worked in agricultural. Nevertheless, this sector was only of minor importance for Swedish exports. Since the Middle Ages, mining and forestry products were Sweden's main exports (Heckscher, 1932).²¹

Historically, Britain has been the most important export market for Swedish products. Demand was particularly boosted after the outbreak of the Crimean War in 1853 (Lindmark and Acar, 2013; Schön, 2012, p. 73-126). Forestry exports grew in importance from the 1840s onwards, and were Sweden's most important export category between 1860 and 1910. In addition, Sweden benefited greatly from increased demand for iron and steel products in the lead up to World War One (Schön and Krantz, 2012).

Despite the importance of natural resource exports for the Swedish economy, Sweden was not among the forerunners in creating radical innovations in the field (Heckscher, 1932). Rather technologies were developed abroad and diffused among Swedish companies. Examples for this are iron forging and the steam engine. While novel iron forging technologies were typically adopted from Germany, the steam engine was originally developed in Britain (Heckscher, 1932; Ostermeyer, 2023). Moreover, industrialization was impeded by limited domestic coal supplies, which increased the cost of steam technology (Schön, 2012, p. 127).

Public-private partnerships were of central importance for the expansion of basic infrastructure and diffusion of modern technology. Enflo and Söderström (2024) introduce the *Swedish infrastructure model* which is centered around *development pairs*²² consisting of a public agency and a privately owned manufacturing company. Historic examples of development pairs include the State Railways (*Svenska järnvägar* – SJ) and ASEA (*Allmänna Svenska Elektriska Aktiebolaget*), the Power Board and (once again) ASEA,²³ as well as the Swedish Telecom and Ericsson. These pairs collaborated to foster the expansion of railway lines, the electric grid, and telecommunications technology, respectively Fridlund (1993). A central characteristic of the Swedish infrastructure model is that the government lays introduces the new technology, while private actors are responsible for linking this larger network to the regional level (Fridlund, 1993; Enflo and Söderström, 2024).

The transition to an industrial society brought also a number of socio-political

²¹Copper had been of major importance until the 17th century, before it was replaced by iron ore and steel thereafter (Heckscher, 1932).

²²This term was coined by Fridlund (1993).

²³This pair collaborated closely for the first half of the 20th, with the purpose to harness hydropower and the establishment of a high voltage transmission grid. After a disagreement over nuclear power generation, their collaboration has been limited to a joint R&D company since the late 1950s.

conflicts. Adoption of novel technology was met with resistance since it was associated with falling industrial employment. During the 1920s, Sweden was the country with the greatest number of labor disputes relative to its population (Molinder et al., 2022)²⁴. Wage differentials, famine, limited economic opportunities, and the potential for upward occupational mobility, incentivized 1.1 million Swedes to leave for the United States during the age of mass migration²⁵ (Lundberg, 1985). This corresponds to roughly 20% of Sweden's population in 1900, who expected better socio-economic prospects elsewhere.²⁶

Moreover, Sweden faced political instability around 1900 (Ericsson and Nyzell, 2017; Molinder et al., 2022). The political landscape was highly fractured and no single party or coalition was able to consolidate power during this period. Indicative for this is that Sweden saw as many governments as Midsummer celebrations between 1921 and 1932 (Riksdagen, 2025).

The year 1932 marks a big transition in Swedish history, when the Swedish Social Democratic Party took office (Lundberg, 1985). Not only was it the first time in over a decade that a government managed to hold onto power for more than two consecutive years, it actually stayed in power for more than four decades (Riksdagen, 2025). The Social Democrats envisioned the construction of a welfare state with a strong government. The "Swedish state should create a "People's home" ²⁷ [...] and provide security to all citizens" (Schön, 2012, p. 218). To achieve this the Social Democrats aimed to minimize socio-economic inequalities and find an effective way to resolve labor market conflicts.

One of the greatest achievements of the Social Democrats was to put a hold to the frequent conflicts between labor unions and employers. Traditionally, workers and the Social Democrats were critical towards rationalization and automation efforts, as they were perceived as threats to employment security (Weinberger, 1997, p. 43,63-64).²⁸ This long-held notion became less dominant during the later 1920s and 1930s. Workers and the Social Democrats noted the potential of rationalization to boost efficiency. Henceforth, labor unions were willing to accept slower wage growth in the short term, as long as this would raise their long-term wage prospects (Molinder et al., 2022; Schön, 2012, p. 219-220). In the Saltsjöbad agreement of 1938, labor unions and employer associations adopted a more cooperative approach, emphasizing collaboration

²⁴Molinder et al. (2022) compare data from North America, the Nordics, and Western European countries.

²⁵This refers commonly to the period between 1850-1930 (Lundberg, 1985).

²⁶See Sjaastad (1962) for a model of costs and returns of human migration.

²⁷*Folkhemmet*

²⁸In their party program from 1920, the Social Democratic Party acknowledges the importance of technological progress for economic growth, but also considers it as instrumental in facilitating the exploitation of industrial labor (Socialdemokraterna, 1920).

over confrontation. From then on the vast majority of wage conflicts were settled without engaging in strikes.

During the first half of social democratic rule, Sweden's economy grew rapidly in a European comparison (Schön, 2012, p. 210). Both during and after World War II demand for Swedish exports was high. During the war Sweden exported particularly iron and agricultural products, while reconstruction efforts raised demand for pulp and paper products. Since Sweden avoided direct involvement in the war, its industries were in difference to neighboring countries intact, allowing the country to benefit from the post war boom (Schön and Krantz, 2012).

While large scale emigration around 1900 can be perceived as indicative of limited economic prospects (Lundberg, 1985), the *Guest Worker Era* in the aftermath of World War II was the complete opposite. During the 1950s and 1960s more than half a million people migrated to Sweden from other Nordic, Western and Southern European countries (Wadensjö, 1975; Jansson, 2014, p. 11-16). Sweden faced along with other Western European countries a sizable labor shortage during this period. Migrants were actively recruited to fill the open positions in the industrial sectors. Migrant workers were particularly drawn to employment in mining, as well as textile, steel, and engineering industries (Jansson, 2014, p. 59-72).

Gains from economic expansion were shared across the Swedish population. While the income share of the top decile exceeded 40% of total wages in the first two decades of the 1900s, this share dropped to 30% by 1950, and merely 22% during the 1980s (Ericsson and Molinder, 2025). Sweden became, alongside the other Scandinavian countries, one of the countries with the lowest levels of income inequality in the world. This is frequently referred to as the *great leveling*.

The limits of the Swedish model

By the early 1970s, Sweden had become one of the most prosperous countries in the world and at the same time maintained a balanced income distribution (Ericsson and Molinder, 2025). Moreover, it was the most industrialized country in Scandinavia (Schön, 2012, p. 299-304). However, it was also heavily reliant on oil imports. Oil accounted for nearly 80% of total energy consumption in Sweden. This can be accounted to an increased use of cars and an expansion of oil-based electricity generation in the 1960s (Kander, 2002, p. 52-55). Dependence on oil imports made Sweden highly susceptible to the effects of the oil crises during the 1970s and 1980s (Energimyndigheten, 2026). The price for crude oil quadrupled, resulting in a general increase in production costs and thus pushing year-on-year inflation to above 10% in the late 1970s (SCB,

2022). In response to the crisis, energy-intensive industries began to search for alternative fuel sources and public actors incentivized an expansion of district heating (Bergquist and Söderholm, 2014; Di Lucia and Ericsson, 2014).

Furthermore, the outbreak of the first oil crisis 1973 demonstrated that the Swedish model was not without its own flaws and revealed a greater structural crisis (Lundberg, 1985; Schön, 2012, p. 16, 302-304). Several of Sweden's major industries, especially shipbuilding, steel, and forestry were adversely affected by the outbreak of the first oil crisis (Eklund, 2007, p. 45-46). Affected industries struggled to adjust employment in face of falling demand, since Swedish labor law at the times was among the strongest in the world (Schön, 2012, p. 302-304). To relieve affected industries while keeping unemployment low, the Swedish government provided massive support and in some cases took over struggling industries. However, this resulted in high inflation. To reestablish competitiveness, the government devalued the Swedish crown. Economic activity stabilized by the late 1970s (Eklund, 2007, p. 45-46).

Over the rule of the Social Democrats, government expenditure grew rapidly in importance within the Swedish economy. Figure 4 illustrates the share of government consumption in Swedish GDP. Increased public involvement in economic activity approximately tipped the share of public consumption in GDP from around 7% in 1930 to 20% in 1970. It reached its maximum in 1980 when government spending accounted for 27% of Swedish GDP.

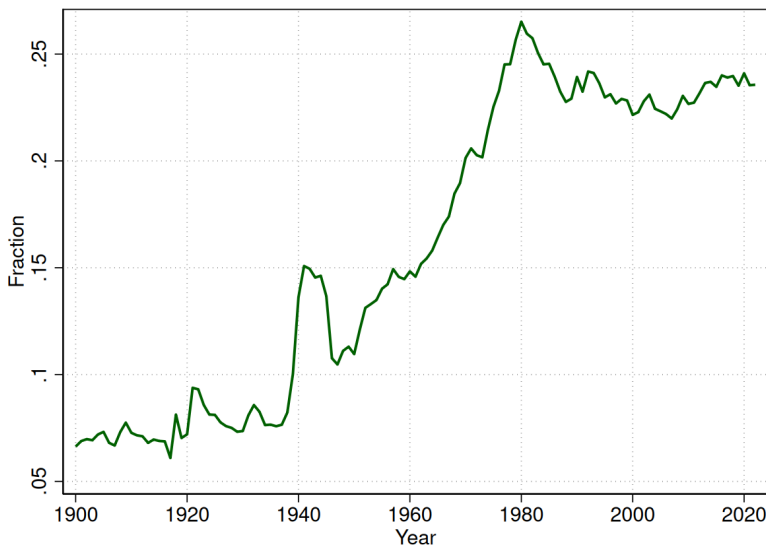
Doubt in the Swedish model resulted in a loss in trust into the party that had established it. The Social Democrats lost elections in 1976, after 44 consecutive years in power (Lundberg, 1985). While the Social Democrats have still been in power for the majority of the period since 1970, their time in office has been interrupted by Center-Right coalitions on four separate occasions. Moreover, since 1998 they have needed to enter coalitions or at least seek support from other parties (see Table 2).

Table 2: Swedish ruling parties, 1936-2025

Time	Ruling party or coalition	Support
1932-1976	Social Democrats	
1976-1982	Center, Moderates, Liberals	
1982-1991	Social Democrats	
1991-1994	Center, Moderates, Liberals, Christian Democrats	
1994-1998	Social Democrats	
1998-2006	Social Democrats	Greens, Left
2006-2014	Center, Moderates, Liberals, Christian Democrats	
2014-2018	Social Democrats, Greens	Left
2018-2022	Social Democrats, Greens	Center, Liberals
2022-present	Moderates, Liberals, Christian Democrats	Sweden Democrats

Source: Riksdagen (2025)

Figure 4: Fraction of government consumption in Swedish GDP, 1900-2020



Source: Schön and Krantz (2012)

The oil crises of the 1970s and 1980s had resulted in a general shift in economic thinking and a growing influence of neoliberal policies. This transformed particularly the financial sector. While banking had been traditional tightly regulated, the Swedish government eased financial controls, and introduced novel financial instruments during the 1980s (Sjögren and Iversen, 2019; Jonung et al., 2009, pp. 301-302). The newly created competition among banks pressed interest rates, and thus fueled lending and property investments across Sweden. However, this trend did not continue forever. By 1990 industrial production declined, decreasing demand for property investments, which resulted in substantial losses for credit companies (Sjögren and Iversen, 2019). Facing rapidly rising interest rates and falling demand for loans, the housing market entered into a rapid downward spiral. Jonung et al. (2009, pp. 19-71) point out that the crisis worsened as firms and individuals sold off their property, driving prices down further.

In addition, macroeconomic conditions deteriorated with the collapse of the Soviet Union in 1992 (Sjögren and Iversen, 2019). Another factor was the German Reunification that applied upward pressure on real interest rates throughout Europe. Rising real interest rates reduced demand for real assets in Sweden which in turn decreased incentives for investments in the housing market (Jonung et al., 2009, pp. 303-304). By late 1990 interest rates for housing loans

exceeded 15%.²⁹ In response housing prices collapsed (Edvinsson et al., 2021).³⁰ The real value of assets in Sweden fell by approximately 30% (Söderström, 1996, pp. 174-179).

As banks started to go bankrupt, the Swedish government became lender of last resort channeling billions of crowns into the banking market (Eckbo, 2010). However, public finances had deteriorated over the two decades leading up to the crisis. One reason for this was the government's commitment to maintaining full employment. Struggling industries were taken over by the state allowing Sweden to avoid mass-unemployment observed in other European countries (Jonung et al., 2009, p. 28). However, in this way public sector employment expanded rapidly, exceeding private sector employment by 1990 (Schön, 2012, p. 304-309). This was however also accompanied by a tripling of government debt between 1970 and the late 1980s, making attempts to maintain full employment increasingly unsustainable. The financial pressure worsened as the crisis continued. Government debt rose close to 2 trillion SEK in 1996, corresponding to 90% of Swedish GDP (SCB, 2022).

The center-right government elected in 1991 privatized several public companies, which was driven by both financial and ideological concerns (Arnold and Barker, 2022). Measures included floating of previously fixed exchange rates, inflation targeting and reducing tax-deductibility of real estate loans (Freeman et al., 2010; Jonung et al., 2009, pp. 305-306). This allowed exchange rates to float and substantial devaluation over the next years promoted export-led growth. At the same time price and wage levels remained stable. This can be partially ascribed to high unemployment, preventing rapid wage increases.

When political power shifted back towards the Social Democrats in 1994, the focus of the Swedish government shifted further towards fiscal consolidation. Public expenditure was cut by amounts similar to 10% of Swedish GDP (Bergman, 2010). Particularly affected by this was public support for basic and applied research which was cut in half (Schilling, 2005, p. 96-97). These policies proved effective in stopping public debt growth by the late-1990s, and debt levels returned to pre-crisis levels by 2005.

Experts considered the Swedish recovery from the crisis as surprisingly quick, particularly in comparison to other countries facing financial crises at the same time, such as Japan and former-socialist countries (Freeman et al., 2010). From the mid-1990 Sweden experienced an export boom facilitated by low exchange rates and a high demand for traditional Swedish export industries such as cars

²⁹This number is based on historic interest rates for 2-year and 5-year bound housing loans from Nordea (2026).

³⁰Edvinsson et al. (2021) estimate that housing prices in Stockholm dropped by 27% between 1991 and 1993, the sharpest decline in real estate prices within their 200-year study period (1818-2018).

and raw materials (Pontusson and Erixon, 2022).

Another important development during this time was the end of Swedish non-alignment policy. Sweden remained formally unaligned during the Cold War, and therefore neither joined the EU nor the North Atlantic Treaty Organization (NATO) during its duration (Johansson, 2003). It only applied for membership in the EU in 1991, and finally joined in 1995. One of the main reasons for policy makers at the time was to secure access to the European single market and strengthening their international position.³¹ In response to the Russian invasion of Ukraine in 2022, Sweden applied for NATO membership and joined the alliance in 2024 (Regeringskansliet, 2026).

However, the Swedish public remained critical of EU membership as it was perceived as limiting the country's autonomy. This is reflected in opinion polls indicating that Sweden was the country with the greatest opposition to EU membership among its member states in 2000.³² and that the wider public in Sweden remains critical to the introduction of the Euro to this day (EU, 2000; Eriksson and Ljungkvist, 2021).

From the late 1990s, Sweden experienced rapid export-based growth. The expansion of information and communication technology (ICT) played a crucial role in this development (Pontusson and Erixon, 2022; Edquist, 2009). The introduction of computer equipment in manufacturing brought substantial productivity gains for manufacturing firms. Moreover, Sweden diversified its exports towards high-technology products.

Nonetheless, a collapse in global demand following the Great Financial Crisis halted Swedish export-led growth trajectory (Pontusson and Erixon, 2022). Instead Swedish recovery from the crisis and a return to economic growth over the following years was facilitated by consumption-led growth. An important facilitator for this has been high real wage growth in comparison to the pre-crisis period, raising domestic demand (Baccaro and Pontusson, 2016).

Sweden is currently (re-)industrializing its northernmost states (Persson and Dymitrow, 2024). While industrial capacity in Northern Sweden has been limited in a historic perspective, it offers manufacturing companies access to natural resources, such as copper, iron, and rare earth elements, collaboration possibilities with high level research facilities, as well as some of the cheapest electric tariff rates in Europe (Smart City Sweden, 2023; Johnson, 2021).³³

³¹Political leaders perceived joining the EU as beneficial due to a decreasing importance of nation states in the international community (Johansson, 2003).

³²In 2000, 38% of Swedes reported that they would preferred if Sweden to left the EU (EU, 2000, p. 8).

³³Industrial consumers in Northern Sweden faced on some days electric tariff rates of merely 0.13 SEK or 0.011€ per kWh, a twelfth of the European average and the lowest on the continent (Thunborg, 2021; Strom-Report, 2021).

Furthermore, the EU is determined to achieve climate neutrality by 2050, a goal manifested with the ratification of the *European Green Deal* in 2021 (ECEEE, 2023). Within these efforts, the president of the European commission Ursula von der Leyen, has emphasized Sweden's central role in this transformation in her first *State of the Union* speech. Of particular interest is the fossil-free steel production in Northern Sweden (EU, 2020). In consequence, Northern Sweden is expected to attract massive investments of approximately 1,000 billion SEK or 120 billion USD over the next decade.

This subsection highlights the importance of natural resource sectors for industrial development and the Swedish economy over all. Furthermore, it illustrates the historical importance of public actors for economic activity in Sweden. Finally, it introduces readers to the impact of the World Wars on the Swedish economy, as well as increasing political and economic volatility since the 1970s, all of which have shaped the emergence of public funding for applied research in Sweden.

3.2 Public innovation funding in Sweden

Public funding for applied research is the central subject of this section. To understand its evolution over time it is crucial to have a basic understanding on the organizations that have been responsible for providing it.

Figure 5 provides an overview over the evolution of public funding institutions operating since the post-World War II period. While not all of these are discussed in this chapter, their responsibilities and operation times are summarized in Supplementary Table 7.

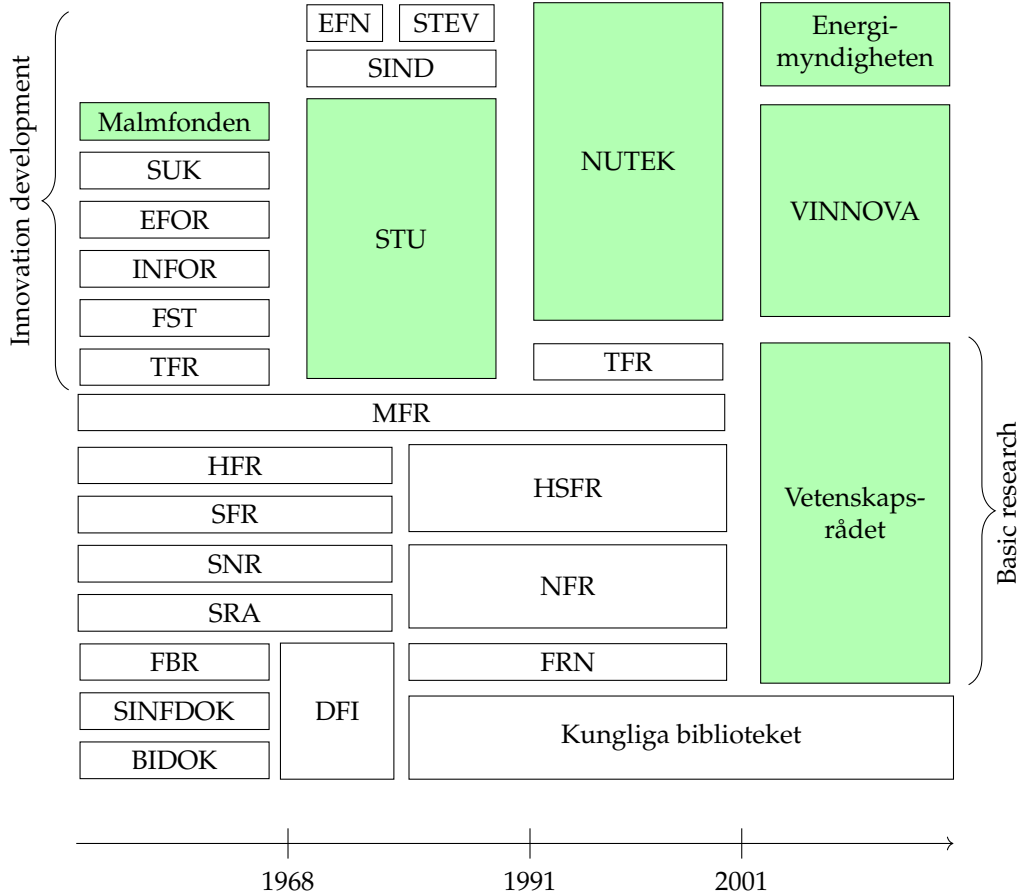
Early development

While many researchers consider the establishment of technical research council (*Statens tekniska forskningsråd* – TFR) in 1942 as the emergence of the Swedish innovation system (Lundin and Gribbe, 2023; Rolfstam and Ågren, 2013; Persson, 2008), it is meaningful to look back further towards the start of industrialization, when the Swedish government began to actively promote research and university education (Weinberger, 1997, p. 33-38).³⁴

During industrialization the Swedish government aimed to strengthen its export sectors, and ensure the expansion of basic infrastructure, including railways, electricity, and telegraph lines. To foster targeted research in its main export sectors, the agricultural institutes (*lantbruksinstitut*), the forest institute (*skogsbruksinstitutet*), and the Geological Survey of Sweden (*Sveriges geologiska undersökningar*), which conducted research in mining, were established around

³⁴For a detailed discussion see Eriksson (1978).

Figure 5: The public funding landscape



Note: Funding years were slightly adjusted. For example, Malmfonden was listed as a separate agency until 1971 and Energimyndigheten was established in 1998 (see Supplementary Table 7). Colored areas mark funding organizations included in our data set.

1900 (Weinberger, 1997, p. 33-38). In addition to this, the government established agencies such as the Swedish State Railways (*Svenska Järnvägar* – SJ), Vattenfall, Telegrafverket, and the Swedish Power Board (*Svenska kraftnät* – SvK) to administer the expansion of modern infrastructure technologies (Fridlund, 1993; Weinberger, 1997, p. 33-38).

Meanwhile, hardly any technical research was conducted. The technical universities KTH (*Kungliga tekniska högskolan*) and CTH (*Chalmers tekniska högskolan*) focused their activities primarily on education (Weinberger, 1997, p. 33-38). Only a few professors at technical universities conducted some applied research. However, this was fully driven by personal interest and thus out of government control.

The outbreak of World War I acted as a catalyst for technical research in Sweden. Support for technical research grew rapidly with the purpose to boost military strength and replacing critical imports (Weinberger, 1997, p. 38-43). The Royal Swedish Academy of Engineering Sciences (*Kungliga Ingenjörsvetenskapsakademien* – IVA) was established right after the end of the war in 1919 (Sundin, 1981, p. 20-22). Industry representatives were interested in including economic thinking, especially revenue optimization in education of engineers, rather than focusing on technical competence alone (Sundin, 1981, p. 63-66). Thereby the focus of technical education shifted towards the creation of commercially viable products.

During World War II, the Swedish government directed research activity towards the military sector, and the substitution of imports whose supply was affected by the war (Weinberger, 1997, p. 78-81). Since Sweden faced a shortage of silicate products during the war, this resulted in the establishment of the Glass Research Institute (*Glasforskningsinstitutet*) in 1945.

Moreover, public funding for scientific research was fundamentally restructured in the middle of the Second World War. The Malm commission was established in 1942, with the purpose to coordinate Swedish research and innovation efforts (Weinberger, 1997, p. 89-92). While major companies and the IVA called for increasing focus on applied research, the Malm commission considered this as a luxury that Sweden could not afford. Instead, research efforts were targeted towards basic research, conducted by universities. Further, a technical research council TFR was founded with the purpose to support long-term projects that were deemed unfeasible for single companies. In a few cases this involved connecting actors who were working on similar issues. After the end of the war in 1945, four more councils were established, targeted towards agricultural and forestry research (*Skogs- och jordbruksforskningsrådet* – SJFR), medical research (*Medicinska forskningsråd* – MFR), social science (*Statens råd för samhällsforskning* – SFR), and natural science research (*Statens naturvetenskapliga forskningsråd* – SNR) (Arnold and Barker, 2022; Eklund, 2007, p. 86).

The establishment of the research councils contributed to an academization of research in Sweden (Lundin and Gribbe, 2023; Rolfstam and Ågren, 2013; Persson, 2008). Research councils directed the vast majority of public funding towards basic research at universities, rather than towards applied research within companies. In addition, research at universities was facilitated by institutional grants. According to Arnold and Barker (2022), this dual structure and heavy focus on basic research is characteristic for a first-generation innovation system.

The creation of the Organization for Economic and Co-operation and Development (OECD) in 1961 saw a renewed interest in research and innovation policy throughout its member states (Henriques and Larédo, 2013; Godin, 2008). The OECD (1963) developed the *Frascati manual* which specified how to collect statistics on R&D indicators. Moreover, it conducted reviews of national science and education policy, with Sweden being the first research subject. Henriques and Larédo (2013) combine information from national reviews to extract a de-facto OECD model for science and research policy. Based on their findings science and research policy should be targeted towards long-term societal and national goals and efforts should be coordinated across different organizations and ministries. Importantly, resources should be shifted towards real world application, hence, applied research (Arnold and Barker, 2022).

The establishment of Malmfonden, EFOR (*Stiftelsen för exploatering av forskningsresultat*), and INFOR (*Institutet för nyttiggörande av forskningsresultat*), aimed to achieve this shift of public resources towards applied research. Funding provided by Malmfonden was targeted towards:

*"large experimental, primarily science-based and technical projects. [Malmfonden's] resources should thus be used, in addition to development projects with a direct industrial connection, for research and development work that, in terms of scope or long-term nature, falls outside what normally falls within the scope of the research council's activities."*³⁵ (Sveriges Riksdag, 1961).

EFOR and INFOR were established in 1963 and 1964, respectively (Sveriges Riksdag, 1964). Both organization focused on the commercialization of research findings, in line with OECD doctrine. While EFOR's operations are aimed at mediation of research results, INFOR was created with the goal to further develop research findings and inventions for industrial use.

Despite these efforts, the OECD (1964) deemed the Swedish research and innovation system as fragmented and poorly coordinated. Policy makers, TFR, trade unions, and industry representatives all took this critique very serious

³⁵Own translation of Proposition 1961:78 §21.

and were in favor of reforms of its research and innovation policy in order to ensure Sweden's competitiveness (Arnold and Barker, 2022).

STU

The Board for Technical Development (*Styrelsen för teknisk utveckling* STU) was established in 1968 (Sveriges Riksdag, 1968). Its purpose is described as follows:

*"It is proposed to establish the Board for Technical Development, a central agency for this kind of support, on the 1st of July 1968. The board is intended to take over tasks from the Technical research council [TFR], Malmfonden, INFOR, EFOR, and the Swedish inventor's office. [...] Apart from funding, STU should conduct certain service activities, among others guidance for inventors, researchers, and dissemination of research results. STU shall have a planning and coordinating function regarding international technical collaboration, information, documentation, as well as certain research stations. A separate council shall coordinate all scientific information and documentation."*³⁶

STU is generally considered as an early example for a second-generation innovation agency (Arnold and Barker, 2022). In difference to the TFR it was not governed by scientists but rather by industry and government representatives, breaking with the tradition of academically driven research. The Social Democratic government was in favor of this reform since it had been at odds with the predominantly conservative research community on several occasions (Weinberger, 1997, p. 140-141).

Nonetheless, it took a few years after STU was first established to create an effective government agency. As outlined in the proposition, STU took over responsibilities from multiple agencies, including, TFR, INFOR, EFOR, Malmfonden, and the Swedish inventor's office (*Svenska uppfinnarkontoret* – SUK).³⁷ The integration of five separate agencies into a single one did not go smoothly. Some competencies, especially administrative capacities, were in over-supply while others were absent and needed to be built up (Weinberger, 1997, p. 385-395).

The situation was even more charged between the multiple expert committees (*facknämnder*) (Weinberger, 1997, p. 385-395).³⁸ Similar to the research councils

³⁶Own translation of government bill 1968:68.

³⁷SUK provided general support for inventors, and information on patenting (Riksarkivet, 2024).

³⁸Separate expert committees existed for the areas of general technical development, biotechnology, medical technology, technical-industrial, inventors, applied mathematics (incl. information processing and computer technology), transportation, material science, geotechnology,

established during the 1940s, STU consisted in its early days of several expert committees. These operated basically independent, since they held full authority to make project decisions as long as they stayed within a given budget. As each committee struggled to maintain its share in total STU funds, the committees frequently threatened to push for independence if they perceived that other committees were favored over them. Weinberger (1997, p. 389) goes so far as describing the situation as an internal *civil war*. These internal conflicts affected even bookkeeping and documentation, as comprehensive data catalogs are only available from 1972 onwards.

To resolve these conflicts STU underwent an internal reorganization in 1972 (Weinberger, 1997, p. 390). The expert committees were transformed into "areas of need" (*behovsområden*) and had from then on merely an advisory function. Project decisions were instead taken by case managers, that acted across sectoral boundaries. The focus of STU rested on providing support for projects connected to public needs (Eklund, 2007). The creation of the "areas of need" is in line with Sweden's tradition of sectoral research programs dating back to the 1960s. During the 1960s and 1970s public funding was primarily directed towards materials, production, and forestry (Åström et al., 2011; Arnold and Barker, 2022; Eklund, 2007, p. 92), while information technology and biotechnology grew in importance after 1980 (Soete and Freeman, 2012; Eklund, 2007, pp. 72-77).

A series of external evaluations investigated the efficiency of STU's work throughout its existence (SOU, 1977; Weinberger, 1997, pp. 454-456, 460-463). One of these was conducted by the so-called STU committee, which criticized STU's continued reliance on the linear model (Weinberger, 1997, p. 417-426). The linear model had been criticized for oversimplifying the innovation process since the late 1960s (see Section 2.2). Further, STU should take a more active role in fostering collaborative innovation, prioritize higher risk projects, provide long-term finance, and introduce follow-ups of approved projects (Arnold and Barker, 2022; SOU, 1977, pp. 224-225). In reaction to this, STU established framework programs (*ramprogram*) in 1977, with the aim to provide long-term funding for projects in target areas, and to foster long-term collaboration (Weinberger, 1997, pp. 427-432). Moreover, detailed peer reviews were introduced in 1979 with the purpose to ensure high scientific quality and coordination across projects (Arnold and Barker, 2022). Despite these reforms, evaluations during the 1980s revealed that the Swedish innovation system remained focused on low and medium technologies (Weinberger, 1997, p. 454-456, 460-463).

astronautics, flutists, electronic components, aeronautics, disability aids, marine technology, remote-sensing, teaching, desalination, and nuclear research (SOU, 1977, p. 21).

NUTEK

A major restructuring of public innovation funding took place in 1991, when the Agency for Technical and Industrial Development (*Närings- och teknikutvecklingsverket* – NUTEK) was established. In addition to STU, NUTEK took over responsibilities from STEV (*Statens energiverket*) and SIND (*Statens industriverket*), creating a combined innovation, energy, business support, and regional development agency (Arnold and Barker, 2022).

Considering that conservative politicians had been highly critical of STU since its foundation, the co-incidence of the timing of NUTEK's establishment with a shift in power from a Social Democratic government to a Center-Right coalition comes as a small surprise (Weinberger, 1997, p. 140-141). According to Arnold and Barker (2022) the government that took office in 1991 believed that it would only stay in office for a single term, rushed to restructure Swedish industrial and research policy.

A government bill from 1991 (Sveriges Riksdag, 1991) describes NUTEK's responsibilities and areas of operation as follows:

NUTEK is the central administrative agency for questions about economic growth and renewal, including energy system transformations. The growing internationalization and broadening of economic policy should be the point of departure for its activity. This includes among others a focus on more general funding rather than selective measures. Moreover, the agency is responsible for government efforts to promote

- 1. technical research and industrial development,*
- 2. establishment and development of small and medium sized companies,*
- 3. a balanced regional development, and*
- 4. energy supply and effective energy use.*

*In connection with these activities, the agency shall be responsible for investigating and evaluating such initiatives from a socio-economic perspective, as well as monitoring international developments and promoting Swedish participation in international cooperation within its areas of operation. Within its areas of operation, the agency shall meet the environmental objectives set by the Government.*³⁹

A major difference in comparison to instructions for STU is the clear focus on environmental protection in the agencies initial instructions. Further, public funding should foster collaborations between small companies and universities. Moreover, it should be noted that NUTEK is instructed to focus on the general provision of public support rather than to specific projects. This can be linked

³⁹Own translation of government bill SFS (1991:960)

to the global trend towards economic liberalism at the time, limiting the scope for government intervention into economic activity (Arnold and Barker, 2022). Other measures of the Center-Right government included the privatization of multiple research foundations, removing them from the control of future governments.

Sweden's accession to EU membership in 1995 has elevated the importance of public funding (Hall, 2019). EU competition laws limit scope of industrial policy. R&D support became basically the only tool to support industrial development. Nevertheless, the weak fiscal position of the Swedish government in the aftermath of the Scandinavian banking crisis, lead to substantial cuts in government spending (Eklund, 2007, p. 101). NUTEK's budget was cut in half between 1995 and 1996, leaving substantially less scope for public R&D support. Despite the novel focus introduced with the establishment of NUTEK, the organization of the public funding system remained debated throughout the 1990s (Eklund, 2007, p. 85-136).⁴⁰ Proponents of the innovation systems literature criticized neoliberal thinking for unrealistic assumptions such as exogenous technological change (Edquist, 1993). They highlight the importance of establishing an innovation agency that centers around the concept of innovation systems. A wish, which was soon fulfilled (Eklund, 2007, p. 128-131).

VINNOVA

The early 2000s saw another reform of innovation funding in Sweden. The new Swedish innovation agency started its operations on the the 1st of January 2001 (Sveriges Riksdag, 2000a, p. 2). The adoption of the innovation systems approach was directly embedded in this reform as the name of the Swedish Governmental Agency for Innovation Systems (*Verket för innovationssystem* – VINNOVA) contains the term “innovation systems” (Eklund, 2007, p. 11).

At the time of writing VINNOVA remains the incumbent innovation agency after 25 years of operation. Its responsibilities are described as follows:

*An R&D authority should be established for needs-driven research and development work to support the innovation system and sustainable development and growth. The R&D authority should take over the areas of responsibility currently handled by the Communications Research Board, the R&D financing parts of the activities of NUTEK and also parts of the area of responsibility handled by the Council for Working Life Research. The Communications Research Board, and the Council for Working Life Research shall be discontinued.*⁴¹

⁴⁰See Eklund (2007) for a detailed discussion.

⁴¹Own translation of Proposition (1999/2000:81)

Similar to NUTEK, VINNOVA should foster collaborations between firms and universities, participation in EU programs, support SMEs, and promote private R&D funding. Furthermore, the support of sustainable development goals is central to VINNOVA's objectives (Sveriges Riksdag, 2000a, p. 38). A more recent description of VINNOVA's responsibilities highlights the importance of strengthening the Swedish innovation capacity and providing companies with the opportunity to test and experiment (VINNOVA, 2025).

The Swedish Research Council

Since the establishment of the first research councils during the 1940s, their activities were limited to specific areas (Eklund, 2007, p. 86). In the late 1990s, the idea emerged to unify these to coordinate research efforts and advice the government more efficiently in regards to basic research (Eklund, 2007, p. 96). This plan was realized with the establishment of the Swedish Research Council (*Vetenskapsrådet* - VR) in 2001 (Sveriges Riksdag, 2000a; Eklund, 2007, p. 128-131).

*The main task of VR shall be to provide support for basic research of the highest scientific quality in all scientific fields. The areas of responsibility currently handled by the Research Councils, the Humanities and Social Sciences Research Council, the Medical Research Council, the Natural Sciences Research Council and the Technical Sciences Research Council will be transferred to the Swedish Research Council. These authorities will be discontinued.*⁴²

At the time of writing, VR is responsible for coordinating and financing basic research in art, clinical therapy, education, humanities, social science, natural science, development, and engineering (Vetenskapsrådet, 2025).

The special role of the energy sector

Due to Swedish reliance on energy imports, energy research has played a central role in publicly initiated research efforts since the early 20th century. Sweden only had minor domestic coal deposits, which were insufficient to meet rising coal needs after 1850, resulting in a massive expansion in coal imports (Kander, 2002, p. 51-52). By 1900, coal was the most important import item, making Sweden highly vulnerable to trade disruption (Kaijser and Högselius, 2019; Weinberger, 1997, p. 78-81). This resulted in major energy shortages during both World Wars, as Sweden's main coal suppliers, Germany and the UK, drastically reduced their coal exports.

⁴²Own translation of Proposition (1999/2000:81)

When the IVA was established at the end of World War I, research efforts were to a high extent directed towards domestic energy sources such as peat, slate, charcoal, and wood (Sundin, 1981, p. 44-60). Moreover, major efforts were undertaken to expand electrification in rural areas, since hydropower was Sweden's most competitive domestic energy source (Kaijser and Högselius, 2019).

The energy question remained of importance after World War II. Efforts were undertaken to establish nuclear power generation, which thanks to major domestic uranium deposits promoted autarky of Swedish electricity generation (Kaijser and Högselius, 2019). Nonetheless, the growth of the automotive industry and their large-scale adoption in society resulted in a rapid increase in oil imports. Thus, Sweden was still highly dependent on energy imports by the outbreak of the 1973 Oil Crisis (SOU, 1989, p. 11-12).

In reaction to the oil crisis the Swedish government implemented the public energy research program (*statligt energiforskningsprogram*) in 1975 (SOU, 1989, p. 11-12). Aims of this program include the reduction of oil use throughout the economy, promotion of domestic energy generation, improvement of energy efficiency, and developing alternative fuels in the transport sector. The energy question became even more acute with the nuclear debate (*kärnkraftsdebatten*) in the late 1970s, which culminated in the referendum of 1980 (Larsson Heidenblad, 2021).⁴³

Two public agencies were tasked with supporting energy research were established in the early 1980s. The Energy Research Board (*Energiforskningsnämnden* – EFN) was established in 1982 with the purpose to support and coordinate long-term research related to the transition of energy systems (Sveriges Riksdag, 1982). Short- and medium-term research was handled by the State energy company (*Statens energiverk* – STEV) (Sveriges Riksdag, 1983). In addition, STEV was tasked with ensuring energy supply and electrical safety.

Nonetheless, these two agencies were merged and dissolved within 10 years of their establishment. Responsibilities from EFN were taken over by STEV in 1990 (Riksarkivet, 2024). Just one year later STEV was merged with SIND and STU to form NUTEK (Arnold and Barker, 2022).

The plan to establish a separate Swedish Energy Agency (*Energimyndigheten*), which combines all energy related responsibilities under the same roof, was announced in 1997 and the agency started its operation in January 1998 (Sveriges

⁴³Swedes were presented with three alternative options, all of which would lead to phasing out nuclear generation. Alternative I and II providing an undefined time horizon for continued nuclear generation and a temporary expansion. In difference alternative III entailed no further expansion of generation capacity and a rapid exit from nuclear generation. The pro-nuclear alternatives were victorious. Consult Holmberg and Hedberg (2009) for a more detailed discussion.

Riksdag, 1997). Energimyndigheten remains in operation at the time of writing (Energimyndigheten, 2023).

Energimyndigheten became not merely the main network authority in Sweden, but its responsibilities even include the diffusion and development of climate friendly energy technologies, as well as the coordination of international collaboration in the energy sector. Thus, Energimyndigheten's operations directly overlapped with those of NUTEK, which had been in charge of energy related research previously. In fact a quarter of NUTEK's 400 permanent employees had been directly working with energy questions, requiring internal restructuring to compensate for the agencies changed responsibilities (Sveriges Riksdag, 1997).

Emergence of alternative funding

In parallel with public funding provided by Swedish innovation agencies, there also exist alternative funding sources. This sub-section summarizes the historic emergence of private foundations, and venture capital, both of which are not directly addressed in this thesis.

The establishment of the Swedish venture capital firms occurred during the 1980s in connection with the liberalization of the previously heavy-regulated banking sector (Lerner and Tåg, 2013). The aim of establishing a venture capital industry was to provide an additional source of funding for small- and medium-sized firms, which have traditionally struggled to obtain larger bank loans (Dahlstrand and Cetindamar, 2000).

The Swedish government took an active role in setting up the first venture capital firm. *Företagskapitalet* was founded in 1973, based on a partnership between several banks and the Swedish government (Herzog, 1987). In 1983, the Swedish government invested even in a private venture capital fund. Nevertheless, high personal and business taxes discouraged entrepreneurship, hampering an expansion of the Swedish venture capital market (Lerner and Tåg, 2013). This changed when the center-right government drastically reduced tax rates during the beginning of 1992 (Dahlstrand and Cetindamar, 2000). While public funding collapsed in the mid-1990s, the amount of venture capital more than doubled between 1991 and 1995. The total volume in 1995 corresponded to 0.95% of GDP (Karaomerlioglu and Jacobsson, 2000).

4 Data and Methodology

4.1 Data

SWINNO

Innovation is frequently used synonymously with technical progress in economic literature (see Section 2.1). Nevertheless, the vast majority of micro-based studies uses patents or R&D spending as proxies for innovation (Cantner and Kösters, 2012; Howell, 2017; Nast et al., 2024; Pless et al., 2020). However, the relationship between patents and commercialized innovations is complicated by the fact that not all innovations are patented, and not all patents come into economic use. Hence, as noted by Pless et al. (2020) other metrics are needed.

A few earlier studies have used smaller selections of radical innovations to analyze the role of public funding in US technology development (Block and Keller, 2009, 2015). In this work innovation data is sourced from the SWINNO database, which captures significant Swedish innovations since 1970 (Sjöo et al., 2014; Kander et al., 2019). For the engineering industry, data is also available from 1871 onwards (Taalbi, 2021). The current database covers 4,838 significant Swedish innovations commercialized between 1970 and 2021.

The collection of innovations is based on screening trade journals according to the Literature Based Innovation Output (LBIO) approach (see Kleinknecht and Bain, 1993 for an early treatment of this methodology). Trade journals were selected on the basis of having an editorial mission to report about technological and other novelty in their respective field. The innovations were included in the database if the trade journal made clear that they are entirely new or significantly improved goods, processes or services that have entered into commercial use. Thus, SWINNO does not contain information on incremental innovations (Taalbi, 2021, p. 228). A recent study by Taalbi and Hylmö (2026) suggests that SWINNO captures approximately 75% of significant innovation in Sweden.⁴⁴

The trade journal articles contain information that allow detailed descriptions of each innovation and key information, including innovating firms, the year of commercialization, collaborating firms and agents and product groups. Previous studies have added additional information to SWINNO. Taalbi (2021) expands the database for the manufacturing industry back to 1908. Other publications have introduced linkages to patent databases (Johansson et al., 2022), identified bioeconomy innovations (Kreutzer, 2026), and added data on firm size (Kreutzer and Taalbi, 2026).

⁴⁴Taalbi and Hylmö (2026) compare innovations included in SWINNO to externally validated innovations. The latter includes Swedish awards and prizes for inventions.

To a limited extent, information on public funding access is captured in the trade journals. However, trade journals do not always report such information and are therefore not representative for the actual extent of public innovation funding.⁴⁵ For this reason, the systematic collection of public funding data was one of the main tasks faced during this thesis project.

Public Funding Database

To build a robust micro-database, I compiled public funding data from several Swedish public funding agencies that operated since the 1960s. It was necessary to combine multiple data sources since the Swedish public funding landscape has undergone frequent restructuring over the study period (see Section 3.2). An overview over the different data sources included in the Public Funding Database can be found in Table 3. It contains a total of 122,079 approved and 37,308 non-approved public funding projects from seven different data sets including archival and digital sources. Total granted amounts sum up to 81,340 Million 2020 SEK.

Table 3: Public Funding Database

	Time	Observations		Source
		Approved	Non-approved	
Malmfonden	1968-1970	135		Riksarkivet
STU	1968-1978	8,174	5,005	Riksarkivet
STINS	1979-2001	39,906	32,303	Riksarkivet
Energimyndigheten	1998-2008	7,180		Energimyndigheten
VINNOVA	2001-2009	7,391		VINNOVA
VR	2001-2007	10,032		VR
SWECRIS	2007-2023	49,260		Vetenskapsrådet (2022)
Total	1968-2023	122,079	37,308	

Note: STINS is a digital database containing public funding projects from STU (1979-1991), as well as NUTEK (1991-2001). SWECRIS combines public funding projects from VINNOVA, Energimyndigheten, and the Research council (2007-2023).

There exist two digitized datasets (STINS and SWECRIS) that capture Swedish public funding over extended periods of time. The name STINS is an abbreviation for support instrument (*STödINstrument*), and is a digital database that was originally created to collect information on regional support in Sweden 1965-2001 (Riksarkivet, 2024). From 1979 onwards, it even contains public funding projects from STU (1979-1991) and NUTEK (1991-2001). STINS was discontinued when NUTEK was dissolved in 2001.

⁴⁵Torregrosa-Hetland et al. (2019) conducted a survey in which 68% of the firms from the Swedish sample reported that they received some public funding, compared to a share of 15% reported in the database.

SWECRIS comprises research projects from several public and private Swedish funding agencies since 2008 (Vetenskapsrådet, 2022). A detailed overview over included organizations can be found in Table 7. For the Public Funding Database projects from VINNOVA, Energimyndigheten and VR are considered.

Relying on STINS and SWECRIS alone was however insufficient since they do not contain information before 1978 nor between 2001 and 2007. To cover the pre-1978 period, archival data from STU and the Malmfonden from the Riksarkivet has been digitized, adding 7,410 additional observations to the data set. The remaining gap between 2001 and 2007, was filled by contacting the main public funding agencies operating during this period, VINNOVA, Energimyndigheten, and the VR, all of which provided digitized data sets.

This thesis focuses on direct financial flows from public funding institutions to firms developing new technologies. That is, I focus solely on projects that contain an aim to develop new technology. In this way this thesis differs from previous studies that linked innovations to public funding if the innovating firm had received any kind of public funding (also non-project specific funding) or had collaborated with a publicly owned company (Block and Keller, 2009; van der Have and Deschryvere, 2026).

In accordance with the chain-linked innovation model, I consider public funding regardless of the stages of the innovation process (Gallagher et al., 2012; Mazzucato and Semieniuk, 2018). This means that public funding is equally considered whether it is provided for the initial research underlying the innovation or for the innovation's commercialization. Unless specified otherwise, the results in this thesis concern all public funding, regardless of its timing.

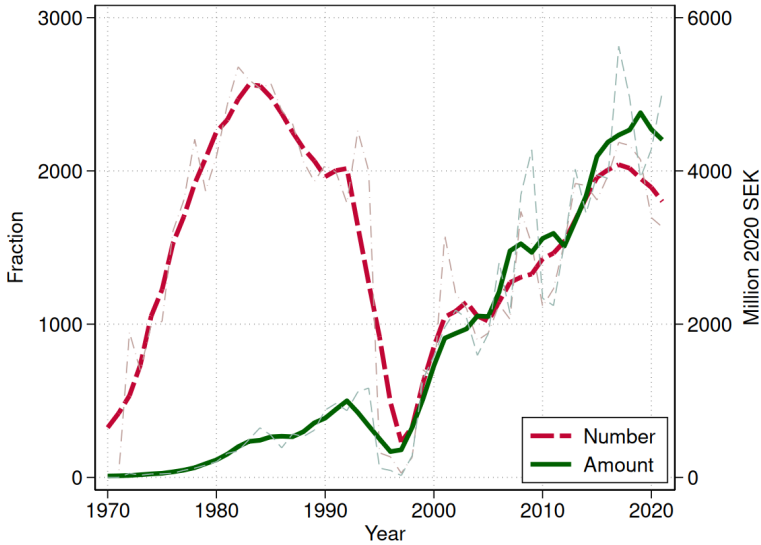
The evolution of projects and granted amounts in the Public Funding Database are presented in Figure 6. The number of approved projects is highest during the 1980s, amounting to over 2,500 per year. Total granted amounts increase by a factor of over 100 across the observation periods, reaching a maximum of 4,760 million SEK in 2019. Both the number of projects and granted amounts collapses during the 1990s. This is related to the substantial drop in public funding in the aftermath of the Scandinavian Banking Crisis (see Section 3.1).

4.2 Linking public funding to innovation data

One of the main challenges in this thesis was the linking of the Public Funding Database to the SWINNO database. The aim of the linking process is to identify innovations and public funding projects, that based on the descriptions derived from trade journals and the Public Funding Database, are deemed to refer to the development of the same product or technology.

Identifying the public funding projects that match the description in SWINNO is challenging due to the sheer size of the Public Funding Database. The Public

Figure 6: Public Funding Database – Number of projects and granted amount, 1970-2021 (5-year moving average)



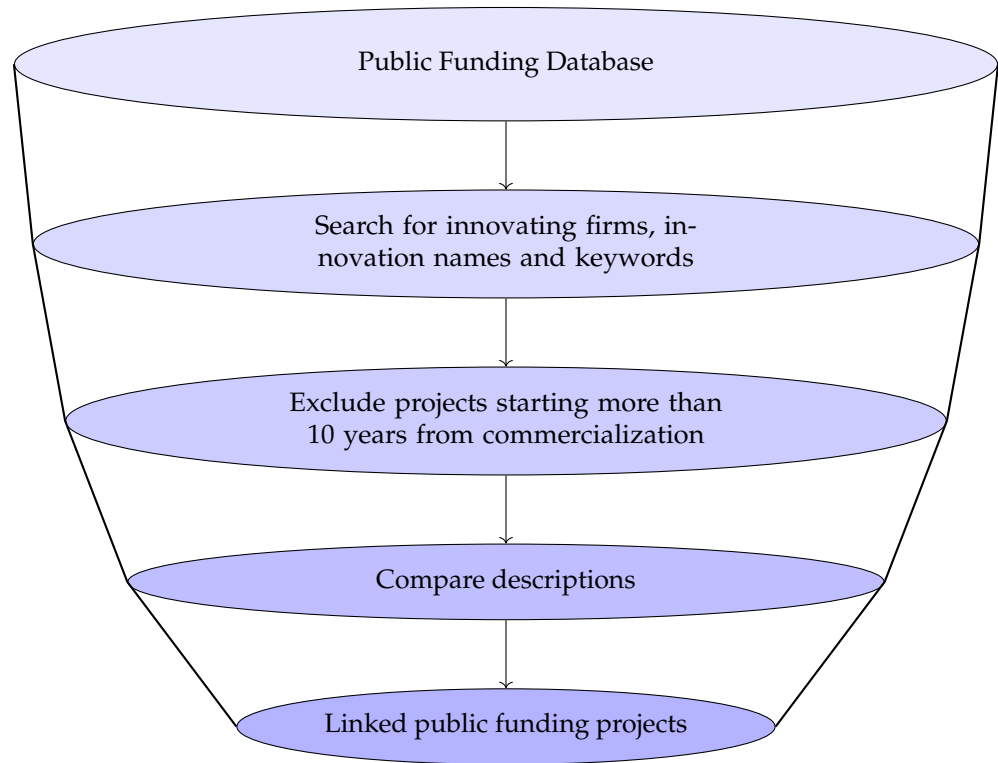
Funding database contains nearly 160,000 projects which could all be considered as potential matches. Therefore, I initially attempted to automatize the linking process. However, to correctly identify links between innovations and public funding projects details in the descriptions must be considered, which language models struggled to grasp.⁴⁶ This was further complicated by the mix of Swedish and English in both databases.

To address these challenges, the linking process has been divided three stages, out of which the first two are automatized. A schematic illustration of the linking process can be found in Figure 7. First, the public funding data is subsetting to decrease the number of potential matches that need to be manually reviewed. The search is based on innovating firms, innovation names and keywords. Second, potential matches that have a start date more than 10 years before or after the commercialization year are excluded from the list of potential matches. Third, the remaining potential matches are manually inspected to identify those projects that best fit the description of the innovation. Decisions are made for each individual public funding projects. A link is only established if the descriptions of the innovation and the public funding projects are sufficiently similar to each other such that they with high certainty refer to the same project. Otherwise, the public funding project is not considered

⁴⁶This was at least the case when I attempted to implement this back in 2022.

as a match. Moreover, matches are non-exclusive, hence, each innovation can be linked to multiple funding projects and each funding project to multiple innovations. Two examples for the linking process innovations are provided in Section 6.

Figure 7: Linking process



Links established between the Public Funding Database and SWINNO can inform data users in two directions. While total public inputs for an innovation can be calculated as the sum of funding for all linked projects, the total innovative output of a research project refers to the number of innovations. Through this linking process, I create the majority of public funding links. A minority of links stems from trade journal information. As illustrated in Table 4, I added 860 additional public funding links through the inclusion of public funding information from the linking process. Thereby, the share of innovations in SWINNO declared to have received public funding rises by 18 percentage points or a factor of four, which is in line with previous estimations by (Torregrosa-Hetland et al., 2019).

To ensure that the final step of the linking process is reproducible, one of the research assistants, without previous access to my linking results, has linked

Table 4: Comparison of public funding shares based on SWINNO and the public funding data set

	Public Funding	
	Yes	No
(1) SWINNO	302	4,536
(2) Public funding data	1,033	3,805
(3) Combined	1,162	3,676

a sample of 50 innovations from SWINNO to the Public Funding Database following the methodology outlined above. Results of the linking process are compared in Table 5. Columns separate results by public funding access based on my results. Rows indicate (1) my results, that of the (2) research assistant, and (3) identical classification by both parties. In 86% of cases we established links between the same innovations in SWINNO and projects in the Public Funding Database. If we only compare overall public funding shares variation between our results is below 5% (22% and 24%, respectively).

Table 5: Comparison of linking results for a sample of 50 innovations.

	Public Funding	
	Yes	No
(1) Our results	11	39
(2) Research assistant	12	38
(3) Identical	8	34

A minor limitation of this analysis is that the Public Funding Database only contains information from 1968 onwards. For this reason, the matching may omit projects with long development time that received public funding prior to this date. Accordingly, public funding propensity among innovations developed during the early 1970 are most likely underestimated.

4.3 Methodology

The thesis departs from an economic historical perspective in the sense that it focuses on analyzing long-term trends rather than the identification causality. Previous work by Nelson and Winter (1985) and Freeman and Louçã (2001) highlight the importance of analyzing descriptive statistics and observing the development of indicators over extended periods of time, particularly when

there exists no one-directed causal relationship between indicators.⁴⁷ This refers to cases when A causes B, but B also influences A.

This thesis applies a broad set of quantitative and some qualitative approaches to investigate the relationship between public innovation funding and innovation outputs. The applied approaches include content analysis, transformer-based text classification, segmented interrupted time series analysis (Paper I), logistic regression (Paper II, Paper IV), social network analysis, probabilistic regression (Paper III), as well as matching approaches (Paper IV).

The purpose of time-series analysis is to observe changes in outcome indicators over extended periods of time. Interrupted time-series analysis (ITS) is a common methodology for assessing the impact of economic crises on health and financial outcomes (Crookes et al., 2020; Turner et al., 2021). In Paper I this is applied to investigate the impact of economic crises on public funding for green innovation development.

Social network analysis (SNA) is central to the analysis in Paper III. SNA is an approach to investigate resource exchange (e.g. information or money) among individuals or organizations (Haythornthwaite, 1996). A growing literature applies methodologies from SNA to analyze the characteristics of innovation networks (Burt, 1992; Ahuja, 2000; Kang and Hwang, 2016; Filippetti and Zinilli, 2023). In Paper III it is used to investigate the brokerage position of innovation agencies, based on measures of network centrality (Kauffeld-Monz and Fritsch, 2013; Cvitanovic et al., 2017).

Paper IV aims to isolate the effect of public funding on innovation outputs through the application of matching approaches (propensity-score matching, nearest-neighbor matching, and inverse probability weighting) (Cerulli, 2010; Czarnitzki and Hussinger, 2018). The aim of applying matching approaches is to minimize differences in covariates between approved and rejected public funding projects.

While most of the analysis in the thesis is based on quantitative methods, content analysis and transformer-based text classification have been applied in Paper I to analyze the direction of innovation policy targets, as well as public funding projects and innovation outputs in greater detail.⁴⁸ Content analysis centers around the formulation of explicit rules that make results reproducible, prevent an arbitrary selection of material, and makes the method transferrable to similar

⁴⁷Nelson and Winter (1985) develop the concept of evolutionary economics, that explains economic change as a complex evolutionary process rather than a simple causation chain. This argument is taken up by Freeman and Louçã (2001), who argue that explanations of long-term development should be based on empirical evidence, highlighting the importance of descriptive statistic and long run trends in socio-economic indicators.

⁴⁸This was a first time for me to apply qualitative analysis in scientific work and was thus among the most challenging but also most rewarding work I have done during my thesis work.

situations (Prasad, 2008). Transformer-based text classification is an algorithm that uses neuronal networks to estimate the likelihood that a description falls into a category.

5 Summary of the individual papers

5.1 Paper I: Shifting priorities – Funding innovation in times of climate crisis and economic turmoil

The first paper of the thesis dives into the literature on public funding directionality. It investigates the allocation of public funding for green innovation in the long run. Moreover, it investigates whether past economic crises have been associated with a backsliding towards conventional technologies.

This paper delves into the history of public funding for green innovation in Sweden, drawing on long-term empirical evidence. Sweden is a particularly interesting country to analyze in this regard, since it was among the first countries to enforce comprehensive environmental protection laws in the late 1960s (Larsson Heidenblad, 2021; Shmelev and Speck, 2018; Hysing, 2014; OECD, 2025). Moreover, it established a centralized innovation agency in 1968 that actively fostered applied research (Weinberger, 1997; Eklund, 2007; Arnold and Barker, 2022).

Three databases are considered for the analysis covering ex-ante and ex-post allocation of public funding. Regulation letters are issued annually by the Swedish government to innovation agencies, outlining their budgets and responsibilities. Content analysis and transformer-based text classification are applied to determine the direction of public funding targets, granted projects, and realized innovations. Moreover, segmented interrupted time series analysis is used to investigate the impact of economic crises on public innovation funding. The paper addresses the following questions:

To what extent has public innovation funding been directed towards green innovation? Historically the Swedish government did not provide much direction to innovation agencies on which technologies to focus. Within larger areas of need innovation agencies were free to make calls of judgment on which technologies to promote. This changed with the establishment of Energimyndigheten in 1998. Regulation letters issued from this year onwards clearly outline which kind of green innovation should be promoted. This applies both to regulation letters issued to main innovation agencies (NUTEK/VINNOVA) and Energimyndigheten.

Public support for energy and environmental innovation varied also in terms of

public funding projects and support for innovation outputs. Energy innovation funding is far more volatile compared to environmental innovation, and closely connected to economic incentives. This changed only in the 2010s, when public support for energy innovation remained high despite of falling energy prices. This decoupling of energy prices and energy innovation development is in line with the findings of Zhang et al. (2021).

How have responsibilities shifted across agencies and time? Until the establishment of Energimyndigheten in 1998, main innovation agencies (STU, NUTEK, VINNOVA) were responsible to support the development of energy and environmental technology. Thereafter, responsibilities were divided. Energimyndigheten should focus on energy related technologies, while main innovation agencies were instructed to promote non-energy environmental innovation.

Nonetheless, regulation letter and ex-post funding data suggest otherwise. Instead of providing a clear division of responsibilities, Energimyndigheten and VINNOVA received basically identical instructions during the early 2000s, which is reflected in actual funding of public funding projects and innovations. In recent years instructions more clearly assign the development of energy innovation to Energimyndigheten, and environmental innovation to VINNOVA. However, VINNOVA is in fact funding more energy related projects than Energimyndigheten in the late 2010s. This is concerning in the light of the literature on effective direction of public funding, pointing to a negative relationship between effective allocation of public funds and overlapping areas of responsibility.

Have economic crises been associated with a backsliding towards conventional technologies? The question whether economic crises are associated with a reduction in public support for green innovation has been addressed by combining a visual inspection of the data and interrupted time series regression. In both cases a negative impact on support of green innovation is observed after the outbreak of the Scandinavian Banking Crisis in 1990. However, neither the First Oil Crisis nor the 2008 Financial Crisis had a similar effect. The visual inspection suggests rather a rise in public support for green innovation around this time, while the regression analysis does not detect any significant effect. Thus, even in countries with substantial public support for a green transformation, severe economic downturns are associated with a decreasing focus on green technology. Nonetheless, a significant correlation was exclusively detected in connection with the most severe crisis faced by Sweden over the past 50 years. This result is surprising given that the majority of existing studies

detect a negative association between environmental policies and economic downturns (Geels, 2013; Andersson and Arvidsson, 2024). A possible explanation for this is that public innovation funding takes longer time to shift in response to economic downturns. Thus, it may not be significantly negatively affected during post crisis recovery.

5.2 Paper II: Picking winners and directions? Public innovation funding in Sweden, 1970-2021.

The second paper of the thesis links the discussions on directionality and efficiency of public funding allocation, and has been developed in collaboration with my main supervisor Josef Taalbi. The idea behind this paper is to use SWINNO linked to the Public Funding Database to investigate which innovations are most likely to receive public funding. Specifically, we are interested in the question whether public funding is correlated with innovation and firm characteristics that are most likely to be underfunded according to innovation literature. This applies among others to major and radical innovation (Block and Keller, 2015; Hall, 2019), energy innovation (Gallagher et al., 2012; Mazzucato, 2013), and small firms (Hall and Lerner, 2010). Within the energy sector we also investigate whether public funding is associated with renewable sources (Acemoglu et al., 2016; Aghion et al., 2016).

Investigating the question whether radical innovation projects are more likely to receive public funding compared to others is closely tied to the debate around *picking winners*. Critics of public funding argue that governments are unable to fund promising innovations, since they lack sufficient information on firms' internal affairs. Therefore, public funding may be inefficient, and more likely to fail than privately funded projects (Helm, 2010; Lerner, 2009; McKenzie, 2017). However, a growing literature argues against this position, highlighting the importance of experimentation and normalization of failure in the innovation process (Rodrik, 2007, 2014).

Further, we analyze the timing of public funding. While some authors argue that public funding is crucial throughout the innovation process, other studies only detect a positive impact during early stages of development (Block and Keller, 2009; Gallagher et al., 2012; Howell, 2017).

Which kind of innovations are associated with public funding? We use logistic regression models to analyze what innovations are most likely to receive public funding. The results reveal that 43% of the most radical innovations relied on public funding. Likewise, energy innovations are more likely to rely on public funding, especially radical energy innovation. Contrary to widely held beliefs that governments are unable to pick winners, our findings highlight

that public funding in Sweden has shaped market conditions, and support has been directed particularly towards highly significant innovations.

Another important trend is the direction of public funds towards renewable energy technologies since 2000. In the post-2000 period, renewable energy innovations were 2.5 times as likely to receive public support compared to non-renewables (see Jugend et al. (2020)). Hence, our results suggest that public funding agencies may have played a crucial role in climate change mitigation efforts by supporting the development of renewable energy technologies and providing the generally needed support for radical innovation activity in the energy sector.

When do innovations receive public support? According to our findings, nearly 80% of innovations received public funding before commercialization. However, most innovations received public funding only a few years before commercialization. This can be interpreted as problematic considering that previous literature indicates that public funding is most effective during early stages of development (Block and Keller, 2009; Gallagher et al., 2012; Howell, 2017).

5.3 Paper III: Quantifying the brokerage power of Swedish innovation agencies, 1970–2021.

The third paper of the thesis takes a closer look at the collaborative dimension of the innovation process, delving into the literature on innovation networks, knowledge brokerage, and network additionality. Collaboration across firm and organization borders generates several benefits for the involved parties, as it allows them to share risks and costs associated with the innovation process (Burt, 1992; Roberts, 2000). However, identifying and establishing contact with suitable collaboration partners proves challenging. To overcome this barrier, knowledge brokers, such as innovation agencies or universities, can step in to bridge contacts between innovative firms (Lomas, 2007; Kauffeld-Monz and Fritsch, 2013; Bornbaum et al., 2015).

Swedish innovation agencies offer an interesting case study to investigate the brokerage power of innovation agencies. The first Swedish innovation agency STU (1968–1991) has portrayed itself as a network broker (Weinberger, 1997), and even after the restructuring of Swedish innovation agencies in 1991 and 2001, STU's successors NUTEK (1991–2001) and VINNOVA (2001–present) have placed special attention to the fostering of innovation activity (Eklund, 2007; Arnold and Barker, 2022).

Weinberger (1997) investigates the brokerage position of STU in a qualitative study, painting a picture of STU like a "spider in its web", using its network

position to orchestrate the formation of contacts between innovative firms and leading research groups in Sweden. Innovation agencies are in close contact with both producers (universities and research institutes) and users of knowledge (innovative companies), putting them in a unique position to foster collaborations between actors with complementary skills and resources. Despite this exemplary position of innovation agencies, there exists so far no study attempting to quantify the brokerage power of innovation agencies, neither in Sweden nor elsewhere.

Moreover, Paper III is closely related to Paper IV in the sense that they fall into the same broader literature on public funding additionality, which is concerned with the question whether public funding is effective in the sense that it creates something that would not exist in its absence (Falk, 2007). Paper III specifically studies network additionality, thus, a change in networking behavior when innovation development is supported with public resources. For this purpose, a probabilistic regression model is used to estimate correlations between collaborator characteristics and public funding access.

To what extent do innovation agencies occupy brokerage positions in the Swedish innovation network? The Swedish innovation network is characterized by small-worldness, which means that most nodes are not directly connected but can reach one another via the innovation agency. Swedish innovation agencies yield substantial brokerage power from a structural perspective. They were directly and indirectly connected to 40-70% and 75-90% of firms, respectively. Moreover, they are the intermediary contact for 40-80% of possible collaborators. Variations arise from the length of the observation period (1970-2021), as well as the creation of a separate agency for energy innovation funding *Energimyndigheten* in 1998.

This finding highlights the importance of innovation agencies in facilitating collaboration among innovative firms. In comparison to previous research, Swedish innovation agencies hold a brokerage position comparable to studies conducting case studies on organizations specializing in connecting producers and users of knowledge (Cvitanovic et al., 2017).

Is innovation agency involvement associated with the creation of unlikely collaboration? The results of the probabilistic regression indicate that public funding ties are associated with a higher likelihood of collaboration between unlikely collaboration partners. While the Swedish innovation network as a whole displays strong signs of homogeneity in ownership, firm size, and degree centrality, the involvement of innovation agencies is correlated with collaborator pairs differing in ownership and degree centrality by 9.5% and 10.2%,

respectively. In addition, the involvement of innovation agencies is positively associated with the formation of regional clusters, particularly promoting connections between technical universities and local companies. Estimation results are robust to variations in tie persistence, and the inclusion of macroeconomic controls.

Surprisingly, collaboration between firms differing in size is only significantly correlated with innovation agency involvement during the 2010s, despite efforts of policy makers to engage particularly SMEs⁴⁹ in innovation development since the 1990s. This might be driven by lacking or ineffective incentives to involve SMEs in innovation development until recent years.

The positive association of public involvement and the creation of diverse collaborator pairs alone cannot be interpreted as evidence for network additionality. Nevertheless, it is promising since innovation literature identifies diverse sets of collaborators as being most likely to generate radical innovations (Filippetti and Zinilli, 2023; Kang and Hwang, 2016; Burt, 1992).

5.4 Paper IV: The effect of public funding on Swedish innovation, 1970–2001.

The question driving the analysis of the final paper of the thesis is very straightforward: does public funding create additional innovation outputs? It falls thus just like Paper III in the literature on additionality, though into a different sub-stream. The paper has been developed together with my co-supervisor Sara Torregrosa-Hetland.

Most previous studies on output additionality consider patents as the output of interest. This literature generally found positive effects, in the sense that firms with access to public funding were more likely to file patents (Czarnitzki and Licht, 2006; Czarnitzki et al., 2007; Plank and Dobliger, 2018; Widmann, 2024). However, patents are only proxies for innovation outputs since they are not necessarily translated into commercialized applications (OECD and Eurostat, 2005, p. 46). In response to this a strand of literature is developing that aims to explore output additionality based on actual innovation outputs (Hewitt-Dundas and Roper, 2010; Prencipe et al., 2024; Bérubé and Mohnen, 2009; van der Have and Deschryvere, 2026).

In the context of this literature, our paper aims to make a number of significant contributions. To the extent of our knowledge, this is the first study to approach additionality with a LBIO-based database of significant innovations, other than the recent article by van der Have and Deschryvere (2026). Second, we consider a longer time frame than that of many studies. A few years or even a decade might

⁴⁹Small- and medium-sized firms

not be enough to capture the effects of public funding. We have three decades of data, which allows us to look at long projects and to explore changes through time in the Swedish innovation landscape (Norrman and Bager-Sjögren, 2010; Taalbi, 2017b). Third, we use data on rejected applicants in order to construct a robust control group. This approach has been used by a number of studies but it is still not the most common, as such data is difficult to obtain (Brown et al., 1995; Söderblom et al., 2015).⁵⁰ Three questions are addressed in the paper:

What innovative firms apply for public funding? Previous research on public funding indicates that there exist differences in the likelihood to apply for public funding across different types of innovative firms. There exist several studies based on Swedish data. While public funding has been traditionally geared towards large firms in Sweden, SMEs are typically more dependent on public funding since they lack access to alternative funding sources (Asheim and Moodysson, 2017; Lerner and Tåg, 2013; Fink and Taalbi, 2024). Moreover, major public funding programs in Sweden were targeted towards urban areas (Asheim and Moodysson, 2017).

The results of the logistic regression indicate that firms were more likely to apply for public funding when they had already obtained it previously, were publicly owned, small, and located in major cities. These findings are in line with previous Swedish and international studies.

Are approved public funding projects more likely to translate into significant innovations? This question is the core of the analysis and was approached by creating a robust control group based on rejected public funding applications, which were matched to approved ones based on alternative matching approaches (propensity score matching, nearest neighbor matching and inverse probability weighting).

We find evidence of strong output additionality, as approved public funding projects were twice as likely than non-approved ones to translate into significant innovations. This finding of positive output additionality is in line with studies from Sweden (Söderblom et al., 2015) and other geographical contexts (Bérubé and Mohnen, 2009; Hewitt-Dundas and Roper, 2010; Prencipe et al., 2024). However, it should be noted that there exist significant differences between the data used in the other studies and that used in our analysis. All these studies refer to later time periods (mid-1990s-2010s), and use dependent variables taken from surveys.

⁵⁰Czarnitzki and Hussinger (2018, p. 1337): "Finally, it would be great to also have information about rejected grant applications to further improve our analysis. We share with the vast majority of previous studies on R&D subsidies that this information is not available."

How is getting more funding translated into innovation significance? The final question investigates in greater detail there exists a positive correlation between firms applying for greater amounts of public funding. We are specifically interested in the question whether firms applied for greater amounts of public funding if this was directed to the development of highly significant innovation. For this question we only consider innovations linked to approved public funding projects.

Given the lack of data on the amount of private R&D funding dedicated to each innovation by the involved firms, we cannot establish causality in this part of the analysis. Instead, we introduce the amount applied for, together with the coverage ratio. The idea is that applications with higher amounts are signaling important projects, which are characterized by higher costs and risks in exchange for higher potential rewards (Mazzucato, 2013).

The results of the logistic regression indicate that projects applying for higher amounts were more likely to generate highly significant innovations. However the size of the estimated effect is rather moderate. We estimate that doubling the applied amount is associated with an 5.6 percentage points increase in the probability of producing a highly significant innovation.

6 Concluding discussion

This thesis contributes to the literature on public funding for innovation activity, specifically to the questions whether governments can steer technological trajectories towards major and green innovation. A key contribution of this thesis is the creation of a novel dataset that directly links public funding projects to innovation outputs. The dataset allows for a more fine-grained analysis since previous studies have merely considered public funding access on the firm instead of the project level. This section summarizes the main findings from the thesis. The discussion is structured around the research questions formulated in the introduction and discusses some future research possibilities.

To what extent is public funding associated with directing technological development towards green innovation? By providing empirical evidence over a 51-year period, this thesis contributes to the discussion on public funding directionality. Obtaining this data from Sweden is particularly interesting since it was among the first countries to target sustainable development as well as providing public funding for applied research.

The results presented in this thesis reveal, that public innovation funding has been targeted towards green innovation since the emergence of applied research funding around 1970. However, funding amounts have been volatile across

time (Paper I and Paper II). In line with previous research by Zhang et al. (2016), R&D funding for energy related research has been closely tied to oil prices until around 2010, when environmental consideration have started to outweigh incentives for energy related research.

Moreover, funding for green innovation is negatively correlated with the largest economic downturn of the Swedish economy over the observation period, the Scandinavian Banking Crisis (Paper I). However, for other crises no similar effect has been detected. This is in contrast with previous findings of Geels (2013), who detects a negative impact of the Great Financial Crisis on public interest for environmental protection.

Another trend that can be observed across time is that governments have formulated clearer guidelines regarding the technologies that should be prioritized over time. Until 1998, innovation agencies were instructed to promote green innovation in general but only in few cases on which technologies they should prioritize. This changed in 1998, when regulation letters clearly outlined where public funding should be directed. Among actually realized innovation projects, green innovation projects are most likely to receive public funding (Paper I and Paper II).

Is public funding directed towards projects that are less likely to obtain funding? One of the major discussion within innovation policy is the question whether governments are able to select the most promising public funding projects or whether funding is provided at random. This question is discussed in Paper II of the thesis. In line with findings from Bérubé and Mohnen (2009) and Hewitt-Dundas and Roper (2010), a robust positive correlation between public funding access and innovation quality is detected. Moreover, public funding is correlated with actors and areas of need that existing literature has identified as requiring additional support. This applies to small firms and the energy sector (Gallagher et al., 2012; Hall and Lerner, 2010; Mazzucato and Semieniuk, 2018).

Moreover, the findings of Paper III indicate that collaboration patterns differ across innovation projects with and without public funding access. Namely, publicly funded collaborations involve more frequently partners that differ from one another in firm characteristics and network centrality. While the design of the analysis is unsuitable to detect causal effects, they point towards positive behavioral additionality (see Wanzenböck et al. (2013)).

To what extent do innovation agencies occupy brokerage positions within innovation networks? Paper III investigates the collaborative behavior of innovating firms in Sweden, and quantifying the brokerage power of innovation

agencies. While network brokerage of the Swedish innovation agency STU has been assessed based on a qualitative analysis by Weinberger (1997), Paper III is the first to estimate the brokerage position from a quantitative perspective, both in Sweden and elsewhere. The results reveal that innovation agencies possess substantial brokerage power. Innovation agencies are linked to 40-70% and 70-80% of innovative firms directly and indirectly, respectively.

Does public funding create additional innovation outputs? Output additionality of public funding is investigated in Paper IV, using non-approved projects to construct a robust control group. Approved projects are twice as likely to generate innovation outputs. The finding of positive output additionality is in line with previous studies that use actual innovations as outcomes (Bérubé and Mohnen, 2009; Hewitt-Dundas and Roper, 2010; Prencipe et al., 2024), and a previous Swedish study (Söderblom et al., 2015).

Further takeaways There exist a few other take aways that are not directly addressed in the research questions. These include the level of continuity despite regular restructuring of the Swedish innovation system. This can for example be observed in regards to the brokerage position of innovation agencies throughout the observation period (Paper III). Moreover, past access to public funding is highly correlated with the probability to receive public funding in the future (Paper II). One explanation for this is that employees of innovation agencies were frequently transferred, when innovation agencies were restructured (Sveriges Riksdag, 1997). Furthermore, information on project decisions indicates that, applications and granted projects were transferred when innovation agencies were restructured.⁵¹

In addition, the findings presented in this thesis indicate that there exists a two-directional relationship between public funding approval and innovation outputs. While public funding approval creates additional innovation outputs (Paper IV), past innovation activity is negatively correlated with public funding approval (Paper II). The existence of two-directed relationship between indicators has been linked to the need of incorporating an analysis of their co-evolution across time (Nelson and Winter, 1985; Freeman and Louçã, 2001). This finding provides support for the choice of an economic historical approach rather than focusing on the identification of causal effects alone (see the discussion in 4.3).

Future research While the findings presented in this thesis provide plenty new insights on public innovation funding, it hints towards several avenues for future research. First of all, I cannot claim full external validity of the results

⁵¹Information on project decisions is available for 6,306 rejected and deferred projects in STINS.

presented in this thesis, since I only consider Swedish data from a limited time period. It would be of interest to collect similar data from other countries and time periods to facilitate a comparison and possibly a generalization of the here presented results. This applies in particular to the brokerage power of innovation agencies, as Paper III is the first to investigate it from a quantitative perspective. In terms of feasibility, Finland would be the most promising candidate, since there exists a comparable database over significant Finish innovations (SFINNO), which has been compared to Swedish innovations in previous studies (Kander et al., 2019; Torregrosa-Hetland et al., 2019).

Second, the addition of private funding data to the combined database would allow for a study of input additionality and a more detailed analysis of total available amounts on the quality of innovation projects. Finally, directly linking the Public Funding Database to patent data would offer possibilities to compare actual innovation outputs to patents, one of the most frequently used proxies for innovation output. This would also make study results more easily comparable to findings from existing literature.

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Appendix

Appendix A: Source material - Public Funding Database

This section contains a more detailed description of the different data sets used to construct the Public Funding Database, that I constructed as part of this dissertation project.

As indicated in Table 3, the Public Funding Database was created by combining a multitude of data sets from several sources and organizations. This required the use of different approaches for data collection, and digitization, in order to construct a uniform database.

Digital data sources are available from 1978 onwards. Information on projects starting this year are only included in digital sources sporadically. Therefore, archival sources from the Riksarkivet, which holds project catalogs from STU and Malmfonden, have been consulted to construct public funding data for the period from 1968-1978.

Archival sources

An overview over the different archival sources is provided in Supplementary Table 1. The archival material used for this project was stored in 24 different folders and contains a total of 9,020 pages. When photographing this data I got help from Jakob Nyqvist who works as a project assistant in SWINNO, and has the major advantage of living within a commuting distance of the Riksarkivet in Täby, located in the Stockholm area.

Due to the sheer size of the source material I considered to automatize the digitization of the documents. In these efforts I got help from Philipp Jonas Kreutzer, a fellow PhD student in the SWINNO project. However, as all of these data sources followed a different format, and even within series the design of pages was inconsistent these attempts were unsuccessful and ultimately abandoned. I ended up digitizing the three archival sources manually, which took approximately 1.5 years of full-time work

Supplementary Table 1: Archival sources

Organization	Series	Folders	Pages	Example
STU	B4 – Project catalog	8	2,217	Supplementary Figure 1
STU	A3A – Decision letters	15	6,574	Supplementary Figure 2
Malmfonden	F4 – Decision letters	1	229	Supplementary Figure 3
Total		24	9,020	

Two different series of projects from STU have been digitized. The first one is a project catalog over approved projects (*Dokumentation över beviljade STU-projekt*).⁵²

Supplementary Figure 1: Example of STU project catalog

Projekt 72/73 per 1973-02-14

ENERGITEKNIK

Behovs- område	STU Dnr Forskningsprojekt	72/73	73/74	74/75
<u>50100 Allmänt</u>				
AFR	71-1467/U1114 Sveriges deltagande i den europeiska organisationens för kärnforskning (CERN) program för en europeisk 300 GeV-accelerator	333 000	334 000	
Atomenergi AB	72-120/U76 Drift av reaktorn R2-U under perioden 72-07-01 - 73-06-30	67 500		
Forskningsrådets laboratorium	72-104/U65 Drift av Forskningsrådets lab	165 513		
IVA	72-370/U297 Energitekniskt utredningsprogram - bedömningar av FoU-behov och försök till strukturering av möjliga FoU-insatser	50 000		
	72-1291/U1032 Stöd åt forskning på kärnenergiområdet och närliggande områden	300 000		

An example from the project catalog is presented in Supplementary Figure 1. Project catalogs are organized by sectors or areas of need (*behovsområde*). The presented example is from the energy sector. For each project, information on grant recipient(s) (*anslagsmottagare*), internal project IDs (*STU Dnr*)⁵³, a project description, and the approved amount of funding, is included. The latter is broken down by fiscal year.

Since I am also interested in rejected projects, I consulted a second series including both accepted and rejected projects (*Ekonomiska beslutsprotokoll (EKB) för beviljande respektive avslag av anslag*)⁵⁴ An excerpt from this data set is presented

⁵²Series B4 in the STU archive.

⁵³For projects starting after 1973, these consist only of 6 digits.

⁵⁴Series A3A in the STU archive.

in Supplementary Figure 2.

Similarly to the project catalogs, this series contains information on project recipient(s), ID, a description, and approved amounts. Moreover, the presented series is organized in a header and two columns, and contains additional variables. The top of the page contains information on responsible case managers (*beslutfattare*), the area of need (*behovsområde*), the decision date (*beslutsdatum*), and other people who were present (*övriga närvarande*).

The left column includes the project id, grant recipient, applied amount, and a description, while the right column contains information on the decision. Rejected projects are labeled as such (*avslag*), whereas granted amounts per year are specified for approved projects.

It should be noted that the STU archive contains quite few observations for the pre-1972 period. This period was marked by infighting across areas of need which only came to an end in 1972 when separate expert committees were transformed into areas of need and decision-making was taken over by case managers (Weinberger, 1997, p. 390). See Section 3.2 for a more detailed discussion.

To complement data from STU between 1968-1971, data from Malmfonden is sourced from the series containing decision letters on public funding projects (*Handlingar rörande avtal (beslutsbrev) om projektanslag*).⁵⁵ An example for one of these decision letters is presented in Supplementary Figure 3. The decision letters from Malmfonden contain the same variables as the STU project catalog over approved projects (see Supplementary Figure 1). Thus, data from Malmfonden does not contain information of rejected applications.

Digital sources

In addition to the archival material, five different digital data sources have been combined to construct the Public Funding Database (see Table 3). These will be presented in greater detail in this section.

STINS was established by NUTEK with the purpose to combine funding information from multiple public agencies, including STU, NUTEK, SIND, and the Swedish Labor Market Authority (*Arbetsmarknadsstyrelsen*). The name is derived from the Swedish term *STödINStrument*, which can be translated as support instrument (Riksarkivet, 2024). STINS consists of multiple sub-datasets, containing information on public funding projects, structural funds, employment support and business support. For the purpose of this thesis, I only included data on public funding projects funded by NUTEK in the final database.⁵⁶ Information from other datasets has however been used to collect data on applicant

⁵⁵Series F4 in the Malmfonden archive.

⁵⁶The included data series is labeled *proj_nutek*.

Supplementary Figure 2: Example of STU series including non-approved projects

XXXXXXXXXXXXX

STYRELSEN FÖR TEKNISK UTVECKLING PROTOKOLL Nr KB - V 60-76/77
Delårsår: MVB

REVISITÄTTER: AD P Forsgren § 1 *PP*
AD T Liljemark § 2 *TL* REVISITÄTTER: 1976-09-28

Förklaringsord: T Liljemark, föredragande *TL*

Nedanstående beslut har förelagts MVN vid sammanträde 1976-09-09 och tillstyrkts.

Ansökan: Företag/Högskola/Ört Projektleddare Esti belopp Projekt	Beslut	Typ av avslag	Typ av projekt	Kategori mottagare	Län
§ 1 76-4751 Prof Lars Th Collin Inst.f.Förbränningsmotor- teknik, CTH 1976/77 271 692:- Avgasluddämpare för för- bränningsmotorer	§ 1 Avslag	2	1:1	O	
§ 2 76-4667 Svenska Utvecklingsaktie- bolaget 1976/77 46 360:- Utveckling av gasrening vid varmförzinkning	§ 2 Kb: 507 02 1976/77 23 180:- m.v.Å. under förutsättning att samma belopp tillskjutes från annat håll Disp.tid 1976-09-15--76-12-31	C	1:6	AB	

Stämman Liljemark
Paul Forsgren

Supplementary Figure 3: Example of decision letters from Malmfonden

STYRELSEN FÖR TEKNISK UTVECKLING
SWEDISH BOARD FOR TECHNICAL DEVELOPMENT
Box 10372 Stockholm 43 • Ljungkärsvägen 22 Stockholm • 08/190190

Beslutsdatum den 25.2.1970
Löp diari nr 69-1343/U961
Projekt nr 51331/1320
Enl protokoll nr AKH STU Dnr 6-69/70

BESLUTSBREV M ALMFONDEN

Anslagsmottagare: AB Bofors Nobelkrut
690 20 BOFORS
Tel 0586/36020

Projektleddare: Å Ohlsson
Tel

Forskningsprojekt: Utveckling av fermentativ framställning
av L-tryptofan ur indol och/eller antra-
nilsyra

Styrelsen för teknisk utveckling har behandlat Er ansökan av den 23.12.1969
och därvid beslutat att på nedan angivna villkor anvisa kr 132 000:— UR MALMFONDEN

	1970/71	1969/70
Låner inkl soc kostnader	56 000:—	56 000:—
Övrigt	10 000:—	10 000:—

- Medlen användes enligt i ansökan angiven plan/~~enligt plan~~ i bilaga 1 och disponeras i huvudsak enligt följande fördelning:
- Arbetet utföres vid: AB Bofors Nobelkrut
under tiden 1.1.1970 - 31.12.1970
- Omst allmänna villkor äger tillämpning såvida ej annat framgår av p 6 nedan.
- Delrapport lämnas
Slutrapport lämnas 30.6.1971
- På skriftlig begäran kan ändring medgivas i ovanstående villkor.
- Bidraget gäller med villkorlig återbetalningskyldighet enligt bilagda särskilda villkor.

Anslaget utbetalas genom: STU adm enhet efter rekvisition åtföljd av specifikation på
havda kostnader och med biläggande av originalverifikationer.

Underkänd förklarar sig härmed beredd anslaget att
i detta beslutsbrev meddelade anslaget och förbinder sig att
ställa sig på de för anslaget uppsatta villkoren till eller
senast 15.3.1970

ARTIEGELAGET BOFORS Bofors den 15.3.1970
Nobelkrut
Anslagsmottagare

Kontaktperson inom STU i tekniska frågor
Avd dir Paul Forsgren

Stockholm den 9 / 3 / 1970
För Styrelsen för teknisk utveckling
Martin Fahren
/ Märtha Lärnstedt

STU A 12.4.8 120413 av 01-002

firms.⁵⁷ Even after the establishment of VINNOVA in 2001, STINS has been administered by NUTEK (Riksarkivet, 2024). Whereas, no new projects were added from this point onwards, information on firm bankruptcies were updated until NUTEK was finally dissolved in 2009.

After STINS was no longer updated in 2001, there existed no database covering public funding projects in a single source until 2008, when SWECRIS was established (Vetenskapsrådet, 2022). In this thesis I used the version of SWECRIS published by the end of 2024, containing a total of 49,260 research projects. Approximately a fifth of the projects included in SWECRIS concern technical funding projects. The database contains information on project IDs, granted amounts, involved organizations, project start and end dates, grant type, sector information, project titles and descriptions.

To cover the seven years in between, I contacted the three public authorities providing innovation finance, VINNOVA, Energimyndigheten, and VR, which all provided me with digitized versions of their project catalogs.

Similar to the archival sources, available information varied across the digital datasets. VINNOVA provided a dataset including project IDs, start and end dates, granted amounts, descriptions and detailed information on recipient firms (including organization numbers). Energimyndigheten provided similar information. Nevertheless, the dataset lacked concrete project start and end dates. Moreover, neither of the two organizations provided sector information on public funding projects. In difference to this, VR's dataset contains detailed information of the sector that the project falls into. Nevertheless, the dataset lacks information on recipients and granted amounts.

Appendix B: Construction of additional variables

This appendix provides an overview over variables that have been used for the analysis. While parts of these are readily available in SWINNO and the Public Funding Database, others have been constructed from either of these data sources. In a few cases external data sources have been consulted to obtain additional information (e.g. on firm size).

Based on SWINNO

Energy innovation

An innovation is considered as an energy innovation if it falls into one or multiple of the subcategories listed in Supplementary Table 2. A novel hybrid electric vehicle would simultaneously be classified as an innovation related to electricity, fuel, and fossil fuel. Therefore, the sum of energy innovations

⁵⁷Primarily the data set *företag* and *projekt*.

falling into each single categories does not add up to the total of 682 energy innovations identified in this study. Categorization was done manually based on the description obtained from trade journal articles.

Supplementary Table 2: Number and share of energy innovations by subcategory

Category	Number	Share
Distribution	70	11%
Electricity	238	34%
Efficiency	304	43%
Emissions	57	8%
Fuel	246	35%
Heat	220	32%
Storage	44	6%
Biomass	39	6%
Fossil	126	18%
Geo	4	1%
Hydro	12	2%
Nuclear	17	2%
Solar	42	6%
Waste	8	1%
Wind	14	2%
Total	682	100%

Note: Categories may overlap and the number and share of energy innovations by category do not add up to the total of 682 or 100%.

Project descriptions in SWINNO contain information on the type of energy use available for all energy innovations, while the energy source is explicitly mentioned only in 252 cases, accounting for 37% of energy innovations. The biggest subgroup of energy innovations, comprising two fifths of all energy innovations are related to the more efficient use of energy. This is followed by innovations related to the use of fuel and electricity which both account for 35% and 32% of all energy innovations, respectively.

Explicit information on the energy source is provided for 252 innovations. In total 101 and 145 innovations are classified as renewable and non-renewable, respectively. In this thesis, biomass, geothermal, hydro, solar and wind energy are classified as renewable sources, while fossil, nuclear and waste are classified as non-renewable sources (see Section 2.1). Six innovations concern hybrid technologies and thus fall into both categories. Fossil fuel represent half of the energy innovations with explicit information on the utilized source. Solar power

is the most popular renewable sources followed by biomass, each accounting for 6% of energy innovations.

Significance

While all innovations in SWINNO are significant, this thesis differentiates between innovations regarding their level of significance. A sizable literature considers the importance of characteristics such as novelty and impact (Dahlin and Behrens, 2005; Kovacs et al., 2019).⁵⁸ However, measuring “impact” requires hindsight, which is unavailable to decision makers. This has made researchers distinguish radicalness *ex ante* and *ex post* (Dahlin and Behrens, 2005). Information on significance captured in SWINNO falls into the *ex ante* category, since trade journals articles report on innovations that are believed to be significant to the general public, stakeholders or specialist readerships.

Three indicators in SWINNO capture novelty and significance. Novelty is considered both on the firm and market level.⁵⁹ Moreover, repeatedly reported innovations are assumed to reflect not only above average significance but also novelty.

These three indicators are combined to distinguish between three different levels of significance:

- *Highly significant innovations* or *radical*, are innovations that were reported at least three times in any journal, or were reported twice but were new to the world market or radical from the firm perspective.
- *Medium significant innovations* are innovations that were reported only once or twice, but were neither new to the world market nor radical from the firm perspective.
- *Low significance innovations* are defined as innovations that were reported only once, and are neither reported as radical from a firm or market perspective. It should be noted that SWINNO does not capture product improvements or incremental innovations in general. Hence, low significance innovations represent a lower register of significant innovations, rather than being representative for incremental innovation.

Patent applications before commercialization

Securing intellectual property rights may strengthen the innovations’ credibility and viability and hence its likelihood of receiving funding. For 1970-2021 patent

⁵⁸See Section 2.1.

⁵⁹A limitation in this context is that market novelty is not always explicitly reported (Sjöö et al., 2014).

information is sourced from Google Patents that aggregates patent records from official patent offices, including the USPTO, EPO, and WIPO (Johansson et al., 2022; Taalbi, 2025). Innovation are considered as having patent applications if the innovation is linked to a patent innovation at any patent office (EPO, USPTO, the Swedish Patent Office and e.g., the Japanese Patent Office). Detailed information about the matching process is available in previous work (see Johansson et al. (2022); Taalbi (2025)).

Collaboration

Information on collaborative innovations is entirely based on trade journal sources. SWINNO contains information on the names, location, and types of the main developing firm and other firms involved in the collaboration process. Collaboration data from SWINNO has been analyzed in previous network studies (Taalbi, 2017a; Chaminade, 2022; Bucaioni et al., 2025; Kreutzer and Taalbi, 2026).

It should be noted that collaboration data in SWINNO is underreporting actual collaborations, particularly when these involve universities during early stages of development (see Torregrosa-Hetland et al., 2019 and Kreutzer and Taalbi, 2026). I encountered evidence supporting this multiple times when linking innovations to public funding projects, and could have theoretically added these collaborations to the dataset. Nevertheless, only collaborations from SWINNO are considered to avoid biasing regression results, since application and receiving public funding is non-random (see Paper II and Paper IV).

Public ownership

Public ownership indicates all firms and organizations that are under full or partial public ownership. Information on ownership is contained as a separate variable in SWINNO, and in some sub-datasets of the Public Funding Database. A firm is declared to be under public ownership if either sources lists them as publicly owned.

Past innovation

Past innovation indicates whether the developing firm(s) created an innovation before commercialization. Previously innovative firms are typically larger established firms, whose innovation behavior differs from smaller recently established firms (Wanzenböck et al., 2013). A binary variable is chosen over a count variable, since this variable would be unbalanced for innovations developed in the later phase of the observation period.

As a special case of firms who developed innovation in the past, the variable top innovators is included in Paper II, indicating the participation of a firm in the innovations process which had developed 10 or more innovations before

the launch of the innovation in question. Since the distribution of the number of innovations is heavily skewed towards companies developing a single innovation (82% of firms in SWINNO), we use a threshold to identify innovations developed by the top 1% innovative firms. To avoid truncating the data in 1970 and losing observations, we used historical data available back to 1908 (Taalbi, 2021). Top innovators include some of the largest corporate groups, such as Ericsson, ABB, Volvo, Saab and Scania.

Location

The location of innovative firms is obtained from SWINNO. It is included as a control variable in Papers III and IV to account for the targeting of Swedish public funding programs towards urban areas (Asheim and Moodysson, 2017). Location data refers to innovative companies' head offices in Sweden. However, the operationalization of the location variable differs between Paper III and IV. Paper IV focuses on distinguishing between major, medium cities and others. The term major city is assigned to firms located in Stockholm, Göteborg, or Malmö, which have been consistently the three most populous cities in the country since the 1870s. *Medium city* applies to firms located in the top 20 biggest cities in Sweden in terms of population size as of 1970, taken from Bäcklund (1991). The top three are excluded from this category. The omitted category are firms located in small cities, which refers to all other locations in this study.

Paper III investigates among others the occurrence of regional collaboration. Therefore, locations of innovative firms have been traced back to their region (*län*). Foreign firm are classified as such. Collaborations between two foreign firms are not considered as regional collaborations since they are located outside of Sweden.

It was necessary to collect additional data on firm location, since the location of collaborating firms in SWINNO is merely available on the national level (Sweden, Finland, Germany, US, etc.). Therefore I collected information on the location of collaborating Swedish firms based on firm names, firm websites, official registries, and web searches. The latter was of particular importance for firms that are no longer in existence.

Based on the Public Funding Database

Approval status

Approval status contains information on whether a project was approved or not. Apart from the analysis in Paper IV, only approved public funding projects are considered in the thesis.

Approved projects may include projects that were ultimately not realized. This can occur when firms abandon planned innovation projects and return the funding they were granted, or when funders withdraw previously granted funding. The latter might happen if firms go bankrupt before initiating their approved innovation project or fail to comply with the conditions attached to the funding.

Granted amount

Information on granted amounts is contained in all sub-datasets contained in the PFD, apart from VR. To account for changes in price levels across time, all monetary values have been expressed in 2020 SEK based on inflation data from the SCB (2022).

Applied amount

Information on applied amounts is available for public funding projects until 2001. Important to note is that this information is available for both approved and non-approved projects.

Coverage

Coverage is the ratio of the granted amount granted over the applied amount. This variable is applied in Paper IV to evaluate the generosity of public funding.

Past funding

Indirect effects of public funding are captured by past funding. Similar to past innovations, this variable indicated whether any of the developing firms has received public funding in the past.

Sector information

Sector information is only available for approximately 50% of observations in the Public Funding Database. This was a concern in Paper IV since some of the subquestions in this paper are based on public funding projects, rather than on innovations in SWINNO.

Public funding projects have been classified based on keywords included in the project descriptions. The keyword lists were generated using Gemini to match the SNI 2007 official classification at the letter level. This initial list was improved through an iterative process, resorting to the descriptions of unclassified projects to identify further keywords. By the end of this process, only 14.6% of the innovation projects remain unclassified. For example, projects were declared to correspond to SNI D "Electricity, gas, steam and air conditioning" if they

included keywords such as *energi*, *elkraft*, *elektricitet*, or *solpanel*, etc.⁶⁰

While the SNI classification at the letter level includes a total of 21 categories, not all these are relevant for innovation projects. In Paper IV we only consider 10 sectors, of which the most frequent in the data are "Manufacturing" (C), "Professional, scientific and technical activities" (M), and "Information and communication" (J).⁶¹ A complete overview of the sectors, including a subset of keywords on which we classify them, is presented in Supplementary Table 3.

Supplementary Table 3: Sector definition

Sector	Keywords
A Agriculture, forestry and fishing	jordbruk, skog, lantbruk odling, växt, fiske, gödsel, djurhållning
C Manufacturing	tillverkning, produktion, industri, fabrik, verkstad, teknik
D Energy	energi, energy, elhandel, kraft, värme, kyla, bränsle, förbränning
E Water and Waste	vatten, avlopp, renhållning, avfall återvinning, sanering, recycling
F Construction	bygg, entreprenad, anläggning, snickeri, måleri, fasad, fönster, renovering, ventilation
H Transportation and storage	transport, logistik, lager, frakt, gods, leverans, distribution
J Information and communication	mjukvara, software, it-konsult, programmering, kod, systemutveckling, app, webb, artificiell, nätverk, maskininlärning
M Professional services	forskning, utveckling, innovation, analys, laboratorium, verifiering, rådgivning, redovisning
Q Health	vård, omsorg, hälsa, terpi, sjuk, klinik, virus, operation

⁶⁰We combined keywords in Swedish and English, since project descriptions often mix both languages.

⁶¹The rest of the sectors we contemplate, with the abbreviated names we use in the paper, are: Energy (D), Construction (F), Health (Q), Transportation and storage (H), Water and waste (E), Agriculture, forestry and fishing (A), and Other. We use "Professional services" hereafter to refer to category M.

Additional variable

Public funding

Refers to whether an innovation obtained public funding. This variable is created based on the linking process outlined in Section 4.2.

Company size

Firm size is a standard control in innovation studies (Jové-Llopis and Segarra-Blasco, 2018; Kesidou and Demirel, 2012; Bronzini and Piselli, 2016; Hottenrott and Lopes-Bento, 2014). It is central to the presented analysis since firm size is a central criterion for public funding coverage in Sweden (VINNOVA, 2021; Energimyndigheten, 2019).

This thesis distinguishes between small, medium, and large firms, as firms with between 0 and 49 employees, between 50 and 199 employees and 200 employees or more, respectively. Data on firm size is available for the majority of firms in SWINNO. It is determined at commercialization and obtained from the SCB (2022) until 2013 and Weidenman (2025) from 2014 onwards (see Kreutzer and Taalbi (2026)).

However, firm size data was not perfectly matched to firms SWINNO. Size information is missing for approximately 9% of innovative firms. This affects among others several universities and university colleges (*högskola*), which are classified as large when employment data is missing.

Linking firm size data to the Public Funding Database proved even more challenging. This was a particular challenge in the analysis presented in Paper IV. We have thus obtained additional employment data for firms in the public funding data for the 1970-2001 period. Exact matches were found for 4,493 firms which were involved in 42,812 public funding projects, corresponding to two-thirds of the sample.

Appendix C: Examples for the linking process

In this section, two examples for the matching process introduced in Section 4.2 are presented. For this purpose, two innovations from the SWINNO database *Carbogel* and *Deep Green* are selected (see Supplementary Table 4). These examples originate from the early and late stages of the observation period, illustrating some of the differences in the Public Funding Database. Moreover, *Carbogel* was developed by a collaboration between AB Scaniainventor and Boliden, while *Deep Green* was developed by a single firm.

Supplementary Table 4: Information in SWINNO

SINNOID	Year	Firm(s)	Innovation name	Description in Swedish
6726001	1980	AB Scaniainventor; Boliden	Carbogel	Miljövänligt, kolbaserat bränslesystem. En stabil kol/vattenslurry. Carbogel är en kolbaserad produkt med oljeliknande egenskaper. Vid tillverkningen finmals kol tillsammans med vatten, varefter bl a svavel och tungmetaller avskiljs och tas till vara. Med en patenterad metod kan det renade kolen sedan lagras, distribueras och användas på samma sätt som vanlig tjockolja. En av de största satsningar Boliden gjort på ett enskilt innovationsprojekt.
12023001	2016	Minesto	Deep Green	Undervattensdrake bestående av turbin, generator och roder för att nyttja vattnets rörelse till elproduktion. Tillverkad av kompositmaterial med 12 meter i vingspann som förankras i havsbotten samt till turbin och generator. När tidvattnet strömmar förbi kan vingen accelereras till tio ggr vattenströmmens hastighet med hjälp av hydrodynamiska krafter.

Carbogel

The first example for the linking process is Carbogel, which is described in SWINNO as a "environmentally friendly, coal-based fuel system [...] with properties similar to oil" ⁶². The project has been developed in collaboration between AB Scaniainventor and Boliden, and was commercialized in 1980 (see Supplementary Table 4).

To identify potential matches, the Public Funding Database is scanned for projects linked to the two developing firms. In total 27 and 53 potential matches were identified for AB Scaniainventor and Boliden, respectively. Out of these 14 are excluded since the projects start a decade after the innovation was commercialized.

When scanning the Public Funding Database for the innovation name, 1 match was returned linked to AB Scaniainventor and 2 for projects from Jernkontoret. Interestingly, Carbogel is also the name of a firm in the Public Funding Database. The 9 projects developed by this firm are also considered as potential matches. In total scanning for firm and innovation names produces 76 potential matches. These are presorted based on the descriptions containing keywords such as "coal (*kol*)", "coal paste (*kolpasta*)", or the innovation name Carbogel. Thereafter,

⁶²Own translation.

12 potential matches remain which are presented in Supplementary Table 5.

Supplementary Table 5: Potential matches for Carbogel

	Firm	Description	Start	End	Amount	Approval
1	Scaniainventor	Kol som energikälla. Undersökning angående ny metod för integration av hantering, distribution, konsumentlagring, förbränning och avgasrening	1974	1974	455,569	1
2	Carbogel	Kol som energikälla	1974	1975	455,569	1
3	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1975	1975	1,560	1
4	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1976	1977	3,007,967	1
5	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1976	1976	751,992	1
6	Carbogel	Kolpasta – utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1978		0	0
7	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1978	1978	2,351,750	1
8	Scaniainventor	Carbogel Heating	1980	1983	1,196,756	1
9	Jernkontoret	Ämnesvärmning med Carbogel lab förs	1983		0	0
10	Jernkontoret	Förgasning av Carbogel	1983		0	0
11	Carbogel	Kolvatten Carbogel	1983	1984	0	0
12	Carbogel	Utveckling av teknik för produktion och karakterisering av högrenade kolvattenbränslen (CAM)	1984	1986	9,853,537	1

In order to confirm or reject matches, the 12 potential matches are inspected closely. Projects 8, 10, and 11, are declared matches as they include the innovation name *Carbogel*, as well as terms such as heating, gasification (*förgasning*), and coal water (*kolvatten*), which all seem to be related to different applications of the innovation. Project 9 contains the term *Carbogel* but is not declared a match as the description indicates a collaboration with the firm of the same name, rather than a relation to the innovation.

Among the remaining seven projects, projects 3, 4, 5, 6, and 7 all include the term coal paste (*kolpasta*). Thus, they refer with high certainty to the innovation in question. Projects 1 and 2 do refer to "coal as an energy source"⁶³, nonetheless the descriptions do not indicate a clear link to the description of Carbogel in SWINNO as the terms do not specifically refer to a coal-water mixture or coal paste. Thus, a total of 9 public funding projects are directly linked to Carbogel.

⁶³Own translation.

Deep Green

The second example for the linking process was commercialized towards the end of the observation period. *Deep Green* is a "underwater dragon consisting of a turbine, generator, and rudder, that uses water movements to produce electricity."⁶⁴ It was developed by Minesto and commercialized in 2016 (see Supplementary Table 4).

The first step to identify potential matches among public funding projects is to search for the name of the innovating firm, returning 9 results. Thereafter, the Public Funding Database is searched for the innovation name. This search returns 5 results, out of which 4 are connected to Minesto. The remaining one is linked to Göteborg university.⁶⁵ In total there exist 10 potential matches for Deep Green, presented in Supplementary Table 6.

In the final step project titles and descriptions are compared to descriptions in SWINNO. For the 5 project descriptions containing the innovation name (projects 1,4,7,8,10), the process is very straightforward as they clearly refer to the innovation in question. Project 10, the only project not lead by Minesto, even refers specifically to *optimization of a tidal power plant in the ocean* and the term *dragon*.

This leaves projects 2,3,5,6, and 9 for further inspection. Among these five projects only project 5 refers directly to tidal power (*tidvattenkraft*). Based on the descriptions in Supplementary Table 6, projects 2, 3, and 5 might potentially be related to the development of Deep Green but the descriptions are very unspecific. Project 9 refers to a project titled "PowerKite", which based on the description cannot be linked to Deep Green. Thus, merely project 5 is declared an addition match, resulting in a total of 6 links to public funding projects.

⁶⁴Own translation.

⁶⁵Deep Green is thus another example for the general underreporting of collaboration with universities in the SWINNO database (see Appendix B).

Supplementary Table 6: Potential matches for Deep Green

	Firm	Description	Start	End	Amount	Source
1	Minesto AB	Verification of the first electricity generating Deep Green device (1:10).	2009	2009	406,000	VINNOVA
2	Minesto AB	Resebidragansökan för Eurostar. Resebidragansökan för Eurostar	2009	2009	15,500	VINNOVA
3	Minesto AB	Resebidrag inför Eurostar Ansökan. Minesto arbetar med många partners inom en rad olika teknologiområden. Projektet som valdes ut för Eurostar-ansökan bedömdes vara högt prioriterat, gynna båda parter marknadsmässigt och ligga i linje med de krav som Eurostar ställer.	2011	2011	25,000	VINNOVA
4	Minesto AB	Deep Green. Deep Green	2011	2012	150,000	VINNOVA
5	Minesto AB	Utveckling och prestandatest av prototyp för strömmande tidvattenkraftverk. Projektet avser experimentell utveckling av en prototyp för Minesto AB:s koncept för strömmande tidvattenkraftverk som bedöms ha förutsättningar för kostnadseffektiv utvinning av el ur långsamt strömmande vatten.	2012	2012	4,924,418	EM
6	Minesto AB	EUREKA Eurostars E!8176 TEHADP. Undersökningar av tillverkningsmaterial, av tillverkningsmetoder och av olika mekaniska utformningar. En tredjepartsgranskning av den första vingen i kommersiell skala pågår. Den första vingen i kommersiell skala är under tillverkning och är fullt finansierad.	2013	2017	3,606,000	VINNOVA
7	Minesto AB	Förstudie för fullskalig testning av Minestos innovativa kraftverk för tidvatten- och havsströmmar. Förbereda och planera för fullskalig verifiering genom testning av Minestos kraftverk DEEP GREEN	2013	2014	200,000	VINNOVA
8	Minesto AB	Ökad stabilitet och livslängd för Deep Green. Öka robustheten och pålitligheten hos kraftverket Deep Green.	2014	2014	2,279,070	EM
9	Minesto AB	Uttekling av projektet PowerKite för ansökan till H2020-LCE2-2015. Uttveckling av projektet PowerKite för ansökan till H2020-LCE2-2015	2015	2015	150,000	VINNOVA
10	Göteborgs universitet	Drakens väg: Optimering av strömkraftverk i havet. Instationära ström- och turbulensfält för tidvattenströmmar utan ett tidvattenkraftverk. Projektet avser också ta fram en modell för att studera Minestos strömkraftverk Deep Greens påverkan av strömningsfältet och vice versa. Samarbete mellan Göteborgs universitet, företaget Minesto och Chalmers Tekniska Högskola.	2016	2018	3,097,914	EM

Appendix D: Additional figures and tables

Supplementary Table 7: Overview of Swedish public funding bodies

Swedish name	Acronym	Start	End	Information	Source
Main innovation agencies					
Styrelsen för Teknisk Utveckling	STU	1968	1991	Promotion of collaboration between academia and industries; focus on "economic areas of special interest", new focus on applied research	Perez Vico and Hallonsten (2019); Åström et al. (2011)
Närings- och teknikutvecklingsverket	NUTEK	1991	2000	Fusion of STU, Industriverket, and Statensenergiverket; ontribute to long-term development of the industrial and energy secotr	Perez Vico and Hallonsten (2019); Åström et al. (2011), Riksarkivet (2024)
Sveriges innovationsmyndighet	VINNOVA	2001		Promotion of sustainable development through the provision of innovation finance	VINNOVA (2025); Sveriges Riksdag (2009)
Related agencies					
Svensk uppfinnarkontoret Malmfonden	SUK	1947	1968	General support for inventors, check inventions, informations on patenting	Riksarkivet (2024)
		1961	1971	Support research and development in the scientific and technical sector with industrial connections; Projects were transferred to the STU after its establishment in 1968	Riksarkivet (2024)
Stiftelsen för exploatering av forskningsresultat	Efor	1963	1968	Mediation of research results	Riksarkivet (2024)
Institutet för nyttiggörande av forskningsresultat	INFOR	1964	1968	Further development of research findings and inventions for industrial use	Riksarkivet (2024)
Fond för skeppsteknisk forskning	FST	1970	1978	Marine technology	Riksarkivet (2024)
Statens Industriverket	SIND	1973	1991	Promote industrial development and finance regionalpolitical development	Nationalencyklopedin (2023)
Energy related agencies					
Statens råd för atomforskning Värmeforsk		1950	1976	Nuclear research	Riksarkivet (2024)
		1968	2015	Finance and direct research in the fields of combustion, heat and environmental technology	Nationalencyklopedin (2023)
Energiforskningsnämnden	EFN	1982	1990	Long-term energy related research; function taken over by Statens energiverk in 1990	Nationalencyklopedin (2023)
Statens Energiverket	STEV	1983	1991	Administration of Swedish energy policy	Nationalencyklopedin (2023)
Energi-myndigheten		1998		Promote transitions towards a sustainable energy system, research in fuel, renewable energy sources, green technology and international climate collaboration	Energimyndigheten (2023)
Elforsk		1993	2015	Research and development company of Swedish electrical companies	Energiforsk (2023)
Fjärrsyn		2006	2015	Research on district heating	Energiforsk (2023)
Svenskt Gastekniskt Center	SGC	1990	2015	Promote research on renewable gas from decomposition and gasification	SGC (2023)
Energiforsk		2015		Coordination and promotion of energy research	Energiforsk (2023)
Research councils					
Vetenskapsrådet	VR	2000		Largest governmental research funding body in Sweden with a budget of almost 8 billion, promotion of research in all scientific areas	Vetenskapsrådet (2022); Sveriges Riksdag (2000b), Nationalencyklopedin (2023)
Statens kommitté för byggnadsforskning		1942	1953	Building sector	Riksarkivet (2024)
		1942	1968	Technical research finance, no support for applied research	Riksarkivet (2024)
Statens tekniska forskningsråd					
Medicinska forskningsrådet	MFR	1945	2000	General and militaristic medical research	Riksarkivet (2024)
Skogs- och jordbruksforskningsrådet	SJFR	1945	2000	Research in agriculture and forestry	Riksarkivet (2024), Nationalencyklopedin (2023)
Statens naturvetenskapliga forskningsråd		1946	1976	Support scientific publications	Riksarkivet (2024)
Statens råd för samhällsforskning		1947	1976	Social science research	Riksarkivet (2024)

Statens nämnd för byggnadsforskning		1953	1960	Building sector	Riksarkivet (2024)
Statens humanistisk forskningsråd		1959	1976	Humanistic research	Riksarkivet (2024)
Byggeforskningsrådet	BFR	1960	2000	Promote reasearch in community planning and the building sector	Byggeforskningsrådet (2016), Riksarkivet (2024)
Humanistisk-samhällsvetenskapliga forskningsrådet	HSFR	1976	2000	Promote and initiate research in social science, humanities, law, and religious studies	Nationalencyklopedin (2023), Vetenskapssrådet (2022)
Naturvetenskapliga forskningsrådet	NFR	1976	2000	Natural science and mathematic basic research	Nationalencyklopedin (2023), Vetenskapssrådet (2022)
Forsknings-rådsnämnden	FRN	1977	2001	Support research and information on research; promote collaboration between research institutions	Nationalencyklopedin (2023)
Teknikvetenskapliga forskningsrådet	TFR	1990	2000	Technologic base research and research training; preference for projects promoting international collaboration	Riksarkivet (2024)
Forskningsrådet för hälsa, arbetsliv och välfärd	FORTE	2000		Research on health, worklife and welfare, annual budget of 800 million SEK	FORTE (2023)
Statligt forskningsråd för hållbar utveckling	FORMAS	2009		Research and innovation funding in environmental, agricultural science, spatial planning; Aiding Sweden in its effort to achieve the environmental targets	FORMAS (2023); Regeringskansliet (2009)
Further funding bodies contained in SWECRIS					
1953 års fond		1953	1964	Support of poor students at Lund and Malmö university	Riksarkivet (2024)
Hjärt-lungfonden		1904		Founded as Swedish National Anti-tuberculosis association. Today general research in the field of cardiovascular diseases	Hjärt-Lungfonden (2023)
Ragnars Söderbergs Stiftelse		1960		Early career support for scientists in economics, medicine, and law	Ragnar Söderbergs Stiftelse (2023)
Familjen Kamprads Stiftelse		2011		Entrepreneurship, sustainability, and elderly care	Familjen Kamprad Stiftelse (2026)
KK-Stiftelsen		1994		Foster Sweden's academic competitiveness, academia-industry collaborations	KK-Stiftelsen (2026)
Naturvårdsverket		1994		Environmental protection	Naturvårdsverket (2026)
Statens Geotekniska Institut	SIG	1944		Promote geotechnical research in Sweden. Its research is of special importance for the construction sector.	SGI (2023)
Östersjöstiftelsen		1994		Development in Eastern Europe and the Baltic region	Östersjöstiftelsen (2023)
Karolinska Institutet		1810		Medical education and research	Karolinska Institutet (2026)
Institutet för arbetsmarknads- och utbildningspolitisk utvärdering	IFAU	1997		Research on labor market and education policy, annual budget of 6 million SEK	IFAU (2023)
Rymdstyrelsen	SNSB	1992		Space research and space applications	Wormbs and Källstrand (2007)
Stiftelsen Riksbankens Jubileumsfond	RJ	1964		Promotion and support of humanistic and social science research; Increasing focus on supporting of long term projects and international collaborations	Riksbankens Jubileumsfond (2017)
Other agencies					
Forskningsbiblioteksrådet	FBR	1965	1979	Provide information for research and development	Riksarkivet (2024), Nationalencyklopedin (2023)
Kungliga biblioteket		1968		Preservation and digitization of information in written, audio, and virtual form; Partially responsible for DFIs operations since 1988	Nationalencyklopedin (2023)
Statens råd för vetenskaplig information och dokumentation	SINFDOK	1968	1979	Provide information for research and development	Nationalencyklopedin (2023), Riksarkivet (2024)
Delegation för rymdverksamheten	SBSA	1972	1992	Space research and space applications	Wormbs and Källstrand (2007)
Biblioteks- och dokumentationssamverkanskommittén	BIDOK	1975	1979	Provide information for research and development	Riksarkivet (2024), Nationalencyklopedin (2023)
Delegationen för vetenskaplig och teknisk informationsförsörjning	DFI	1979	1988	Provide information for research and development	Riksarkivet (2024), Nationalencyklopedin (2023)

Author contributions

For the included papers, the table below indicates the work preformed by Johanna Fink in the corresponding projects. There were also continuous discussions between all collaborators throughout the project and especially in early stages.

<i>Paper</i>	<i>Concept</i>	<i>Data collection</i>	<i>Implementation</i>	<i>Evaluation</i>	<i>Writing</i>
I	●	●	●	●	●
II	◐	◐	◐	◐	◐
III	●	●	●	●	●
IV	◐	◐	◐	◐	◐

The dark portion of the circle is intended to illustrate the proportion of work and responsibilities assigned to Johanna Fink, but is more formally defined as:

- Johanna Fink led and did almost all the work.
- ◐ Johanna Fink led and did a majority of the work.
- ◑ Johanna Fink was a contributor to the work.
- ◒ Johanna Fink was a minor contributor to the work.
- Johanna Fink did not contribute, except for proofreading.

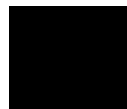
Concept Coming up with the ideas and working out the details in theory.

Implementation Writing the software required for the paper.

Evaluation Conducting the experimental evaluation and analyzing the data.

Writing Drafting and editing the paper

Paper I



Shifting priorities - Funding innovation in times of climate crisis and economic turmoil*

Johanna Fink[†]

August 20, 2026

Abstract

In the face of climate change and environmental degradation, governments are striving towards directing technological progress towards *green* technologies. Nonetheless, economic crises are frequently associated with a shift in priorities, favoring economic growth over environmental protection. Moreover, unclear responsibilities across public agencies are associated with inefficient allocation of funds and resources. This paper aims to contribute to these debates by analyzing shifts in the direction of public innovation funding for green innovation over five decades (1968–2023). Green innovations encompass environmental and energy-related innovation. Sweden is selected as a research subject, since it was among the first countries to actively promote environmental protection and applied research, starting in the late 1960s. Three questions are considered: 1. To what extent has public innovation funding been directed towards green innovation? 2. How have responsibilities shifted across agencies and time? 3. Have economic crises been associated with a backsliding towards conventional technologies? Content analysis, transformer-based text classification, and time series analysis are used to determine the direction of ex-ante and ex-post allocation of public funding. Data is obtained from regulation letters, a database over applied public funding, and a database over significant Swedish innovations. The results reveal that public funding has been directed towards green innovation over the observation period. However, public funding for energy innovation has been more volatile and closely connected to financial incentives. While responsibilities for the development of green innovation have been divided between main innovation and energy specific agencies since the late 1990s, this division of responsibilities is not reflected in ex-post funding data. The agencies have in fact a rather complementary role in funding energy related research. Funding for green innovations dropped significantly in the aftermath of the Scandinavian Banking Crisis. No similar drop can be observed following the oil or the Great Financial Crisis. This finding contrasts previous findings linking the Great Financial Crisis to a drop in environmental performance.

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1 Introduction

Rapid technological progress and economic growth over the past two centuries have contributed to an unprecedented increase in wealth and living standards. Innovations such as steam engines, internal combustion, and semiconductors play a crucial role in this development as they transformed our modes of production, transportation, and communication (Kuznets, 1980; Aghion et al., 1998). However, the spread of modern technology resulted in a massive increase in population and consumption of natural resources, straining the environment. Neither the use of coal and oil to power steam engines and cars, nor the use of copper sulfate in computer chips was without consequences. Fossil fuel combustion for energy use is the main contributor of human made climate change (IPCC, 2018; Akpan and Akpan, 2012). Further, the use and disposal of toxic materials causes environmental pollution (Ruberti, 2023).

During the 1960s, a wider public became aware of the adverse effects of economic activity on environmental quality, especially the link between local and global pollution. Sweden was one of the first countries to enforce comprehensive environmental protection laws (Thörn and Svenberg, 2017; Larsson Heidenblad, 2021; Shmelev and Speck, 2018; Hysing, 2014; OECD, 2025). The most prominent example for this is the environmental protection law *miljöskyddslagen*, implemented in 1969 (Regeringskansliet, 1969). Firms were pushed to adopt and develop green innovation, since the law prohibited the direct disposal of untreated waste products.

In parallel to the environmental movement, Sweden took another step to direct technological development. It was among the first countries to adopt a second generation innovation agency *Styrelsen för teknisk utveckling* (STU) in 1968, characterized by offering direct support to applied research instead of limiting its activity to funding basic research (Weinberger, 1997; Eklund, 2007; Arnold and Barker, 2022). This offered the Swedish government a second channel to direct technological progress, namely by actively supporting the development of innovation in line with environmental policy targets.

However, history has shown that environmental protection is typically neglected in favor of short-term growth during economic crises (Geels, 2013; Andersson and Arvidsson, 2024). Existing literature has linked this to a decline in interest for environmental protection among the wider population, as well as the political repercussions of large-scale job loss in existing industries. Since the foundation of STU and the implementation of the 1969-environmental protection law, Sweden has faced four major economic crises.

Moreover, the public funding system has been re-organized twice since it was first established (Fink and Taalbi, 2024; Arnold and Barker, 2022). In connection

to this, responsibilities for promoting green innovation¹ shifted across agencies. In particular there exists a separate entity to fund energy innovation since 1998. Previous research has pointed to the risk of inefficiencies when responsibilities across public agencies are not clearly divided (Handley, 2008; Tetlak et al., 2025). This paper delves into the history of public funding for green innovation in Sweden, drawing on long-term evidence (1968-2021). The following questions will be addressed: 1. To what extent has public innovation funding been directed towards green innovation? 2. How have responsibilities shifted across agencies and time? 3. Have economic crises been associated with a backsliding towards conventional technologies?

Three databases are considered for the analysis covering ex-ante and ex-post allocation of public funding: 86 regulation letters outline the responsibilities of innovation agencies, the Public Funding Database covers over 105,000 public funding projects granted between 1968-2023 (Fink and Taalbi, 2024; Fink and Torregrosa-Hetland, 2026), and SWINNO, a database containing information on over 4,838 significant Swedish innovations commercialized between 1970-2021 (Sjöo et al., 2014; Kander et al., 2019). These sources are analyzed based on content analysis and transformer-based text classification. Moreover, segmented interrupted time series analysis (ITS) is used to investigate the impact of economic crises on public innovation funding.

This study contributes to the literature on public innovation funding, by adding quantitative evidence to long-term shifts in public funding allocation. Unlike the majority of existing research, it draws on actual innovation data instead of patent data (Popp, 2002; Noailly and Smeets, 2015; Aghion et al., 2016). Patent data is a common proxy for innovation despite the fact that patented products are not necessarily commercialized and thus put to economic use (Taalbi, 2025; Oslo Manual, 2005, p. 46). The direction of public funding for energy innovation in Sweden has previously been addressed in Fink and Taalbi (2024). However, these findings have not been directly linked to changes in public funding targets nor granted public funding projects. Moreover, the paper by Fink and Taalbi does not consider environmental innovations.

The remainder of this paper is structured as follows: The second section provides an overview of the existing literature of public funding cyclicity and direction. Relevant background information on the environmental movement, public funding landscape and economic crises in Sweden is provided in Section 3. Section 4 presents data sources and methodology. In Section 5, the results of the analysis are presented. Discussion and concluding remarks can be found in Section 6.

¹Green innovation refers in this paper to technologies targeted towards sustainable resource use, reduction of environmental pollution, and energy technology. A more detailed definition is provided in the data section.

2 Cyclicity and directionality of public innovation funding

The rationale behind public intervention in innovation activity is closely related to the theory on market failure (Arrow, 1962; Nelson, 1959). When private companies make R&D investment decisions, they focus on generating maximum gains for themselves in the short run. Furthermore, they try to minimize inherent risks of the innovation process (Hall and Lerner, 2010; Warwick and Nolan, 2014). However, what is ideal for an individual company is not necessarily best for society as a whole. Individual actors seldom internalize positive externalities of their innovation activity on other members in society. This problem is amplified in the energy sector, where extended development time and the need for complementary infrastructure raises obstacles for individual firms (Fouquet and Pearson, 2012; Gallagher et al., 2012; Mazzucato and Semieniuk, 2018). According to their findings, relying on private investment alone results in an underinvestment in R&D activity.

Even if private companies engage in innovation development, the technologies pursued by them might not be in line with societal interests. Empirical evidence suggests that future innovation builds on the existing stock of knowledge. Hence, if firms produced non-green innovation in the past they tend to continue to do so in the future (Aghion et al., 2016; Noailly and Smeets, 2015). This can be considered as a market failure (Acemoglu et al., 2023). Environmental quality can be considered as a public good (Pearce and Palmer, 2001). While all actors can benefit from public goods, they tend to over-consume them, since they do not take the well-being of others into account when making production decisions. Governments thus face a dual challenge. They should provide additional resources for innovation development, while ensuring that they are *directed* towards projects that do not harm environmental quality.

Economic literature discusses different types of government interventions to direct technological development towards green innovation. One stream of the literature centers around the role of carbon prices and the existing stock of knowledge. Popp (2002) uses US patent data (1970-1994) to estimate the effect of energy prices on the production of energy efficient innovations. The author identifies both energy prices and existing knowledge stocks as main determinants. Noailly and Smeets (2015) investigate the direction of technological innovation in electricity generation based on patent data (1978-2006) from 5,471 European firms. According to their findings, the shift towards green innovation is driven by small specialized rather than large incumbent firms. Aghion et al. (2016) use patent data (1965-2005) from 3,412 firms and individuals to estimate the impact of carbon prices on direction of technological change. Similar to Popp (2002), they find that both increases in fuel prices and the existing stock of

knowledge promote green innovation.

While these studies provide a long-term perspective on green transitions, they omit another important channel for the government to direct innovation development: public funding. This is addressed in a second stream of literature, focusing on the potential of public innovation funding to create and shape new markets through the provision of financial resources (Plank and Dobliger, 2018; Sánchez-Sellero and Bataineh, 2022; Mazzucato et al., 2015; Mazzucato, 2018; Wang et al., 2024).

The formulation of public funding targets can be an important tool in directing public innovation funding. Clearly formulated targets signal to both applicant firms and funding organization which type of technological development are most desirable (Mazzucato, 2016, 2013). However, it should be considered that single technologies are insufficient to address the current climate crisis. In line with the theory on risk diversification, governments should opt for supporting multiple rather than a single technology (Koumou, 2020).

Linked to this discussion is the establishment of clear guidelines for dividing responsibilities across agencies. Tetlak et al. (2025) investigate the effectiveness of public local waste management in the light of novel EU regulation, while Handley (2008) focuses on local-federal cooperation in the intergovernmental grant systems in the US. Handley's findings suggest that shared responsibilities raise the risk of producing inefficiencies. This applies even to different institutions within the government apparatus.

A growing literature applies content analysis to determine the direction of public policy. Huang et al. (2010) investigate policy priorities among environmental issues in China, based on 1,564 government documents issued between 1999 and 2008, focusing on pollution types, high-polluting industrial sectors, environmental policy instruments, and implementation of international treaties. Environmental protection gains prominence over the observation period, and that measures are diversified. The number of policy documents concerning environmental issues nearly triples over the observation period, from 173 to 498 issued in 1999-2000 and 2007-2008, respectively. Moreover, command-and-control measures (e.g. emission controls) are complemented with economic incentives, such as pollution charges and subsidies.

A long-term study by Zhao et al. (2020) investigates air control instruments.² The study identifies a significant increase in the number of documents issued on air-pollution as well as a broadening of the policy instrument with the implementation of the ninth 5-year plan in 1996. From then on policy makers increasingly combine regulatory with market-based and voluntary instruments.

²The authors conduct computer assisted content analysis on 148 Chinese policy documents issued by the central government between 1973 and 2016.

Nonetheless, China returned to a predominantly regulatory approach in 2016. What these studies demonstrate is that governments' environmental support is not constant across time. This issue is also taken up in a growing literature focusing on the link between economic downturns and investments into green innovation and sustainable development. The vast majority of these studies focus on private investment in R&D activity. Aghion et al. (2010, 2012) investigate the relationship between economic volatility, credit constraints and R&D investments, detecting a counter-cyclical relationship in sectors with low credit constraints. However, in the presence of high credit constraints R&D expenditure is slow to re-bounce after economic downturns. This has negative implications for long-term growth prospects in the absence of alternative finance such as public innovation funding, since private funding will remain at unsustainable levels.

Pellens et al. (2024) investigates public R&D funding among 28 OECD countries between 1995 and 2017, differentiating between innovation leaders, followers, and moderate innovators. While public funding overall is pro-cyclical, public R&D funding remains more stable compared to private funding during economic downturns. Technological forerunners, like Sweden, tend to even conduct counter-cyclical funding to compensate for a lack of private funding. Within the energy sector, empirical evidence suggests that public support for energy innovations has been closely coupled to energy prices (Gallagher et al., 2006). Public investment has risen sharply during the oil crises of the 1970s and 1980s. However, public funding has been limited for the following two decades, harming innovation development as they require stable investments over extended periods of time. Nonetheless, a decoupling of public funding and energy prices can be observed since the early 2000s. This is in line with the findings of Zhang et al. (2021), who analyze the direction of public funding for energy innovation on the global level between 2000-2018, and Fink and Taalbi (2024), who analyze which type of innovations are more likely to receive public funding in Sweden. The authors identify the early 2010s as the times when energy prices decouple from public R&D for energy technologies. This is accounted to an increasing awareness of the climate crisis among governments and the wider public.

Another interesting discussion is related to the changing impact of economic crises on environmental behavior over the course of its duration. Supporters of the *green growth* perspective consider economic crises as an opportunity for sustainable development. This can among others be achieved by promoting job growth in green industries and provision of incentives to reduce negative externalities (Bowen and Fankhauser, 2011).

Governments have increasingly issued green stimulus packages in response to economic crises. O'Callaghan et al. (2022) link green stimulus packages to

higher job creation and greater economic growth compared to investments in non-aligned technology. Their study encompasses the Great Financial Crisis and Covid pandemic. The weight of research in green technologies within stimulus packages has increased approximately by a factor 1.5 across the two crises, reaching nearly 20% during the Covid pandemic.

The success of green stimulus packages in regard to lobbying and government agendas is investigated by Tørstad et al. (2024), based on US and Canadian data from the Great Financial Crisis and Covid pandemic. According to the authors findings, a clear government agenda emphasizing environmental protection efforts is central for issuing a meaningful green stimulus program. Even in the presence of influential fossil fuel lobbies, the Obama and Trudeau administrations were thus able to steer economic recovery towards green technology.

Other studies connect economic crises to *backsliding*, referring to a reduction in public attention for sustainable development during times of economic hardship (Ashford et al., 2012). While economic crises are at least initially considered as a window of opportunity, hence, a possibility to redirect economic activity towards sustainable development. In practice however, limited resources tend to be concentrated in established industries and activities, leaving less funds available for green innovation (Geels, 2013).

Geels (2013) studies the Global Financial Crisis, drawing on investment for renewable energy innovation, policy document, and public opinion polls with a focus on the UK. Initial reactions to the crisis were largely in favor of green growth as public stimulus packages promoted sustainable development, particularly in the energy sector. However, in the latter part of the crisis this trend reversed as governments faced more stringent financial constraints, refocusing resources to suffering conventional industries. A similar pattern has been observed by Andersson and Arvidsson (2024), who study the impact of the Covid pandemic on environmental behavior among Swedish firms, based on survey data from 2020-2021. The majority of firms declare that they consider the pandemic as an opportunity to redirect their efforts towards sustainable development. However, their behavior was not aligned with this as they redirected resources away from environmental purposes. Thus, empirical findings on the Great Financial Crisis and Covid pandemic are rather in line with the literature on *backsliding*.

3 The Swedish case

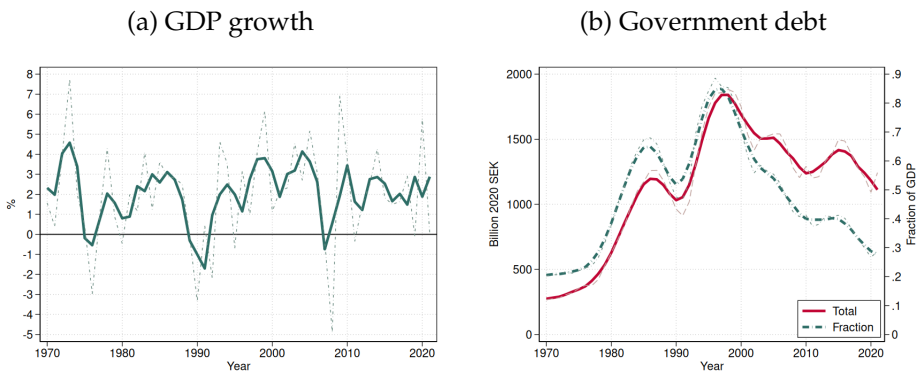
3.1 Economic crises

Over the course of the study period Sweden has experienced several economic downturns and recessions. In this paper recessions are defined as negative

growth in GDP on the annual level.

Figure 1a displays Swedish GDP growth between 1968-2023. Sweden experienced a decrease in its GDP three times over the observation period: the oil crises of the 1970s and 1980s, the Great Financial Crisis, and the Scandinavian Banking crisis.³ While the majority of international readers are familiar with the first two, the most severe recession out of Swedish perspective was the Scandinavian Banking Crisis that affected the majority of Nordic economies during the 1990s (Eckbo, 2010). This sub-section will provide a short overview of these three crises and their effect on the Swedish economy as a backdrop for the following analysis.

Figure 1: Macroeconomic indicators, 1970–2021



Source: Nilsson et al. (2023) and SCB (2023).

Note: GDP growth is a 3-year moving average while Government debt is a 5-year moving average.

While Sweden has one of the cleanest energy mixes in Europe today, it was heavily reliant on oil imports at the onset of the study period. In 1970, oil accounted for nearly 80% of total energy consumption in Sweden, primarily used for fueling cars and the expansion of oil-based electricity generation in the 1960s (Kander, 2002, pp. 52-55). However, this made Sweden highly susceptible to the effects of the oil crises during the 1970s and 1980s (Energimyndigheten, 2026). The price for crude oil quadrupled, resulting in a general increase in production costs and thus driving up year-on-year inflation to over 10% in the late 1970s (SCB, 2023). In response to the crisis, energy-intensive industries began a search for alternative fuel sources and public actors incentivised an expansion of district heating (Bergquist and Söderholm, 2014; Di Lucia and Ericsson, 2014).

³The Covid pandemic will not be discussed in greater detail since it only occurred one year before the end of the observation period.

The next major economic crisis faced by Sweden was the Scandinavian Banking crisis. While banking had been traditional tightly regulated, the Swedish government eased financial controls and introduced novel financial instruments (Sjögren and Iversen, 2019; Jonung et al., 2009, pp. 301-302). The newly created competition among banks pressed interest rates, and thus fueled lending and property investments across Sweden.

However, this trend did not continue forever. By 1990 industrial production declined, decreasing demand for property investments, which resulted in substantial losses for credit companies (Sjögren and Iversen, 2019). The housing market entered into a rapid downward spiral, facing rapidly rising interest rates, and falling demand for loans. Jonung et al. (2009, pp. 19-71) point out that the crisis worsened as firms and individuals sold of their property, driving prices down further and further.

In addition, macroeconomic conditions deteriorated with the collapse of the Soviet Union in 1992 (Sjögren and Iversen, 2019). Another factor was the German Reunification that applied upward pressure on real interest rates throughout Europe. Rising real interest rates reduced demand for real assets in Sweden which in turn decreased incentives for investments in the housing market (Jonung et al., 2009, pp. 303-304). By December 1990, interest rates for housing loans exceeded 15%.⁴ In response, housing prices and asset prices collapsed (Edvinsson et al., 2021; Söderström, 1996, pp. 174-179).⁵

As banks started to go bankrupt, the Swedish government became lender of last resort, channeling billions of crowns into the banking market (Eckbo, 2010). However, public finances had deteriorated over the two decades leading up to the crisis (see Figure 1b). One reason for this was the governments commitment to maintaining full employment. Struggling industries were taken over allowing Sweden to avoid mass-unemployment observed in other European countries (Jonung et al., 2009, p. 28). However, in this way public sector employment expanded rapidly, exceeding private sector employment by 1990 (Schön, 2012, pp. 304-309). This was however also accompanied by a tripling of government debt between 1970 and the late 1980s, rendering attempts to maintain full employment unsustainable. The financial pressure worsened as the crisis continued. Government debt rose to almost 2 trillion SEK in 1996, corresponding to 90% of Swedish GDP.

A center-right government took office in 1991. It took several measures to address the crisis driven by both financial and ideological concerns (Arnold

⁴This number is based on historic interest rates for 2-year and 5-year bound housing loans from Nordea (2026).

⁵Edvinsson et al. (2021) estimate that real estate prices in Stockholm dropped by 27% between 1991 and 1993, the sharpest decline within their 200-year study period (1818-2018). Söderström (1996, pp. 174-179) estimate that the real value of Swedish assets fell by approximately 30%.

and Barker, 2022). Measures included the privatization of public companies, floating of previously fixed exchange rates, inflation targeting, and reducing tax-deductibility of real estate loans (Freeman et al., 2010; Jonung et al., 2009, pp. 305-306). These measures facilitated a devaluation of the Swedish crown over the next years, which promoted export-led growth. At the same time, high unemployment kept wage levels stable.

From the mid-1990s, the focus of the Swedish government shifted further towards fiscal consolidation. Public expenditure was cut by an amount equivalent to 10% of Swedish GDP (Bergman, 2010). In response, public debt stopped growing by the late-1990s, and returned to pre-crisis levels of approximately 50% by 2005. Experts considered the Swedish recovery from the crisis as surprisingly quick, particularly in comparison to other countries facing financial crises at the same time, such as Japan and former-socialist countries (Freeman et al., 2010).

Twenty years after the Scandinavian Banking Crisis broke out in Sweden, the bankruptcy of Lehman Brothers set in motion a series of events that displayed several similarities to the events in Scandinavia during the early 1990s (Eckbo, 2010). While several Southern European countries faced public debt crises in the early 2010s, this was not the case in Sweden (Febrero et al., 2019). While absolute government debt increased slightly, levels remained stable in terms of GDP (see Figure 1b).

3.2 The emergence of the environmental movement

Sweden is considered a pioneer in environmental policy (Shmelev and Speck, 2018; Hysing, 2014; Lundqvist, 1972). Its capital, Stockholm, was the venue of the first UN climate conference in 1972, demonstrating Sweden's commitment to promote climate change mitigation efforts (Larsson Heidenblad, 2021, p. 9). Nonetheless, only six years prior merely academic and political circles were aware of the gravity and global nature of environmental degradation. The general public considered it merely as a local issue (Larsson Heidenblad, 2021, p. 57).

Evidence for human-driven environmental degradation was observed and discussed in some academic and elite circles since the late 1940s (Larsson Heidenblad, 2021, p. 57). Further, the link between local and global pollution moved into the focus of academic discussion with the occurrence of acid rain and acidification of Swedish lakes due to pollution in other parts of Europe during the 1960s (Almer and Dickson, 2021; Staaf and Bertills, 1992).

The publication of *Silent Spring* in 1962 is frequently considered as the breakthrough of the environmental movement and growing awareness of environmental concerns among the general population (Beyl, 1992; Lear, 1993). The

book addresses the consequences of chemical pollution on the environment, particularly the impact of the insecticide DDT (*dichlorodiphenyltrichloroethane*) on bird populations. Nonetheless, Carson's book does not address the link between local and global pollution (Lear, 1993; Beyl, 1992).

General awareness on the link between climate change and the unsustainability of the contemporary socio-economic development path became known to a wider public in Sweden thanks to a series of debate articles by leading scientists (Larsson Heidenblad, 2021, pp. 29-33). Of special importance was the book "*Plundring, svält, förgiftning*" (Plundering, famine, poisoning) by Hans Palmstierna (1969), which was discussed in all major Swedish newspapers, lifting the environmental debate to the center stage of public debate.

Polls conducted by the Swedish Institute for Opinion Polls (1969) and Folksam (1969) suggest that the Swedish public were exceptionally willing to issue bans aimed at protecting the environment. 84% of participants wanted to levy charges on polluting industries, and 54% of participants were even willing to accept lower economic growth rates in exchange for avoiding environmental degradation.

In response to public demand for greater environmental protection, governments introduced several policies to foster environmental protection. The Swedish government issued an environmental protection act in 1969 (Regeringskansliet, 1969), which targeted unrestricted release of sewage water and environmental poisons.

The reduction of global greenhouse gas (GHG) became a greater concern only in later years. The most well-known example is the introduction of a carbon tax in 1991, one of the first in the world. In 2022 Sweden still had the highest carbon tax in the world amounting to 118€ per ton (Andersson, 2019; Ministry of Finance, 2022). This tax effectively curbed emissions particularly in the transport sector. Based on a synthetic control group approach, Andersson (2019) estimates that the introduction of the carbon tax reduced Swedish carbon emissions by 11%.

One reason for the early introduction of environmental restrictions in Sweden is the close connection between scientists and the government (Larsson Heidenblad, 2021). Since Sweden is a relatively small country with a handful of renowned universities, elite circles are closely connected. This fosters exchange and collaboration between the countries leading researchers and politicians.

While Sweden was early to introduce environmental protection regulation, laws were in several instances rolled back when political power shifts occurred. This is exemplified in this section based on the ban of nuclear power production in 1980, and the 2017 environmental targets.

Sweden was one of the early movers in reducing carbon emissions. This was closely connected to the phasing out of fossil fuel based electricity generation

between 1970 and 1990 through an expansion of nuclear generation capacity (Qvist and Brook, 2015). A main supporter of nuclear generation were the Social Democrats, the dominant party during most of Swedish modern history. Under their consecutive 44-year lasting rule from 1932 until 1976, nuclear power was commercialized and a total of 12 reactors were commissioned (Tekniska museet, 2025).

However, the 1979 Three Mile Island incident in the US raised concerns regarding the potential dangers of nuclear generation (Edberg and Tarasova, 2016). After the Social Democrats lost power to a center-right coalition in 1976, a referendum on the future of nuclear energy in Sweden was held in 1980. The Swedish public voted by a narrow margin for phasing out nuclear energy step-wise until 2010. Nonetheless, many voters of the Center party that traditionally preferred an immediate stop of nuclear generation were unsatisfied with the result of the referendum. This triggered the emergence of the Swedish Green party (*Miljöpartiet*), which is still present in the Swedish politics today (Hultman, 2015).

Until the early 2000s, it seemed like the nuclear age in Sweden was coming to an end. In line with the energy directive from 1997, the two nuclear reactors in Barsebäck (Western Scania) were shut down in 1999 and 2005 (Sveriges Riksdag, 1997; Edberg and Tarasova, 2016; Hultman, 2015; Hysing, 2014). However, when the center-conservative *Alliance* government took office in 2006 and abandoned plans from their own rule 26 years earlier to discontinue nuclear generation by 2010. This was surprising given the traditional anti-nuclear stance of the Center party. Despite critics especially from the Green party nuclear power is still of central importance for electricity generation in Sweden, accounting for 29% of total generation in 2023 (IEA, 2025).

A more recent example are the climate policy targets, issued by the Swedish government in 2017, in response to the 2015 Paris agreement (Miljödepartementet, 2019). An overview of the environmental targets is presented in Table 1. The majority of these focus on the energy sector. Among others, the Swedish government aims to achieve net zero emissions by 2045, raise energy efficiency by 50% until 2030, and generate electricity exclusively from renewable sources by 2040. To achieve these targets the Swedish government reformed the energy taxation system in favor of renewable energy sources (Energimyndigheten, 2021). Moreover, an independent climate council was established to evaluate the environmental policies proposed by the government (Regeringskansliet, 2017). When these targets were first adopted they found great support both among Swedish majority and opposition parties. Thus, they were considered as resilient in case of power shifts (Millot et al., 2020). Nonetheless, the targets did not even survive a single shift in political power. The take over of the conservative government in 2022 resulted in the adjustment and later in the abandonment

Table 1: Swedish key climate and energy policy objectives

Target	Target year	Base year
Net zero emissions	2045	1990
-75% emissions from sectors outside the EU	2040	1990
-63% emissions from sectors outside the EU	2030	1990
-40% emissions from sectors outside the EU	2020	1990
-70% emissions from domestic transport	2030	2010
50% energy consumption from renewable sources	2020	
100% electricity generation from renewable sources	2040	
50% increase in energy efficiency	2030	2005

Source: Miljödepartementet (2019)

of the climate target issued in 2017. By 2024 any related targets were removed from the regulation letters issued to public funding (Saltebro, 2024).

These shift in environmental policy were so severe that they drew international attention. The OECD (2025) warns that recent policy shift create uncertainty and harm environmental protection efforts. Also, the Swedish environmental agency warned that Sweden would not be able to meet its climate target if it was to continue its current policies (TT, 2025; Rosen Fondahn, 2025).

3.3 Public innovation funding

Public authorities in Sweden recognized the importance of research for economic growth since Sweden entered its industrialization in the late 19th century. In reaction to this, publicly funded research institutes targeted towards Sweden's main export sectors were established around 1900. These include the agricultural institutes (*lantbruksinstitut*) in Ultuna and Alnarp, the forest institute (*skogsbruksinstitutet*), and the Geological Survey of Sweden (*Sveriges geologiska undersökningar*) (Weinberger, 1997, pp. 33-38).

The Malm commission was established in 1942, with the purpose to coordinate Swedish research and innovation efforts (Arnold and Barker, 2022; Weinberger, 1997, pp. 89-92). While major companies and the Royal Swedish Academy of Engineering Sciences (IVA) called for an increasing focus on applied research, the Malm commission considered this as a luxury that Sweden could not afford. Instead, research efforts were targeted towards basic research, conducted by universities. Further, a technical research council (*Statens tekniska forskningsrådet* TFR) with the purpose to support long-term projects that were deemed infeasible for single companies. In a few cases this involved connecting actors working on similar issues. After the end of the war in 1945, four more councils were

established, targeted towards agricultural and forestry research (*Skogs- och jordbruksforskningsrådet SJFR*), medical research (*Medicinska forskningsråd MFR*), social science (*Statens råd för samhällsforskning SFR*), and natural science research (*Statens naturvetenskapliga forskningsråd SNR*) (Arnold and Barker, 2022; Eklund, 2007, p. 86).

However, this lacking focus on applied research was critically scrutinized in an OECD investigation from the early 1960s, criticizing the Swedish innovation system's lack of support for applied research (Arnold and Barker, 2022). The establishment of *Malmfonden*, *Stiftelsen för exploatering av forskningsresultat EFOR*, and *Institutet för nyttiggörande av forskningsresultat (INFOR)*, aimed to achieve this shift of public resources towards applied research (Sveriges Riksdag, 1961, 1964). Despite these efforts, the OECD (1964) deemed the Swedish research and innovation system as fragmented and poorly coordinated. Policy makers, TFR, trade unions, and industry representatives all took this critique very serious and were in favor of reforms of its research and innovation policy in order to ensure Sweden's competitiveness (Arnold and Barker, 2022).

The Board for Technical Development (*Styrelsen för teknisk utveckling STU*) was established in 1968 as Sweden's first central innovation agency (Sveriges Riksdag, 1968). Its purpose is described as follows:

"It is proposed to establish the Board for Technical Development, a central agency for this kind of support, on the 1st of July 1968. The board is intended to take over tasks from the Technical research council [TFR], Malmfonden, INFOR, EFOR, and the Swedish inventor's office. [...]"

*Apart from funding, STU should conduct certain service activities, among others guidance for inventors, researchers, and dissemination of research results. STU shall have a planning and coordinating function regarding international technical collaboration, information, documentation, as well as certain research stations. A separate council shall coordinate all scientific information and documentation."*⁶

STU is generally considered an early example for a second-generation innovation agency (Arnold and Barker, 2022), where funds were no longer only directed towards basic research but rather towards applied research and product development.

During the early years of STU's existence, organizational constraints limited the organization's efficiency. STU took over responsibilities from multiple agencies, including the TFR (*Statens Tekniska Forskningsrådet*),⁷ EFOR (*Stiftelsen för Exploatering av Forskningsresultat*), INFOR (*Institutet för Nyttiggörande av Forskn-*

⁶Own translation from Government Bill 1968:68.

⁷Founded in 1942 with the purpose to support long-term projects unfeasible for single companies in the area of technical basic research (Arnold and Barker, 2022; Weinberger, 1997, pp. 89-92).

ingsresultat),⁸ *Malmfonden*,⁹ and the Swedish inventor's office SUK (*Svenska Uppfinnarkontoret*).¹⁰ The integration of five separate agencies into a single one did not go smoothly. Some competencies, especially administrative capacities, were in over-supply while others were absent and needed to be built up (Weinberger, 1997, pp. 385-395).

The situation was even more charged between the multiple expert committees (*facknämnder*) of which STU consisted in its early days (Weinberger, 1997, pp. 385-395). Expert committees operated basically independently, as they held full authority to make decisions on projects as long as they stayed within their budget. As each committee struggled to maintain its share in total STU funds, committees frequently threatened to push for independence if they perceived that other committees were favored over them. Weinberger (1997, p. 389) goes so far as describing the situation as an internal "civil war". To resolve these conflicts an internal reorganization of STU took place in 1972 (Weinberger, 1997, p. 390). The expert committees were transformed into "areas of need" (*behovsområden*) and had merely an advisory function, project decisions were instead taken by case managers. These internal conflicts affected even book-keeping and documentation, as comprehensive data catalogs are only available from 1972 onwards. The creation of the "areas of need" is in line with Sweden's tradition of sectoral research programs dating back to the 1960s. During the 1960s and 70s, public funding was especially directed towards materials, production and forestry (Åström et al., 2011; Arnold and Barker, 2022; Eklund, 2007, p. 92). From the 1980s onwards, information- and biotechnology become of major importance (Soete and Freeman, 2012; Eklund, 2007, pp. 72-77).

During the early years of STU's operation, projects deemed the most promising were approved as long as funds were available. A series of external evaluation investigated the efficiency of STU's work throughout its existence (SOU, 1977; Weinberger, 1997, pp. 454-456, 460-463). Especially during the 1970s, these pointed out several weaknesses of STU, such as a lack of coordination between projects, long-term finance, as well as insufficient follow-ups with coordinators of approved projects (Arnold and Barker, 2022; SOU, 1977, pp. 224-225). In reaction to this, STU established framework programs (*ramprogram*) in 1977, with the aim to provide long-term funding for projects in target areas, and to foster long-term collaboration (Weinberger, 1997, pp. 427-432). Moreover, detailed peer reviews were introduced in 1979 with the purpose to ensure high

⁸Founded in 1963 and 1964 respectively, EFOR and INFOR fostered the commercialization of research findings (Sveriges Riksdag, 1964).

⁹Created in 1961 with the purpose to support large, long-term research projects with industry connection falling outside the scope of the research council (Sveriges Riksdag, 1961).

¹⁰Established in 1947, SUK provided general support for inventors, as well as information on patenting (Riksarkivet, 2022).

scientific quality and ensure coordination across projects (Arnold and Barker, 2022).

A major restructuring of public innovation funding took place in 1991, when the Agency for Technical and Industrial Development (*Närings- och teknikutvecklingsverket* – NUTEK) was established. In addition to STU, NUTEK took over responsibilities from STEV (*Statens energiverket*) and SIND (*Statens industriverket*), creating a combined innovation, energy, business support, and regional development agency (Arnold and Barker, 2022). A government bill from 1991 (Sveriges Riksdag, 1991) describes NUTEK's responsibilities and areas of operation as follows:

§1 NUTEK is the central administrative agency for questions about economic growth and renewal, including energy system transformations. The growing internationalization and broadening of economic policy should be the point of departure for its activity. This includes among others a focus on more general funding rather than selective measures. Moreover, the agency is responsible for government efforts to promote

- 1. technical research and industrial development,*
- 2. establishment and development of small and medium sized companies,*
- 3. a balanced regional development, and*
- 4. energy supply and effective energy use.*

In connection with these activities, the agency shall be responsible for investigating and evaluating such initiatives from a socio-economic perspective, as well as monitoring international developments and promoting Swedish participation in international cooperation within its areas of operation. Within its areas of operation, the agency shall meet the environmental objectives set by the Government.¹¹

It is no coincidence that the reorganization of the innovation agency took place in the same year as the power shift from the social democratic Party to the center-conservative government in the midst of the Scandinavian Banking Crisis in 1991. According to Arnold and Barker (2022), the Conservative government believed it would only stay in office for a single term, rushing to restructure Swedish industrial and research policy. Moreover, STU had been established under social democratic rule and had ever since its establishment been unpopular among conservatives.

Nonetheless, combining all different innovation-related agencies in a single one did not diminish the debate around an effective restructuring of the public funding system during the 1990s (Eklund, 2007, pp. 85-136). Proponents of the innovation systems literature criticized the lacking regard for the actual nature

¹¹Own translation of government bill SFS(1991:960)

of technical change in neoclassical economic thinking. Edquist (1993) voiced the need to establish an innovation agency that took innovation networks into account.

This was realized with the public funding reform of 2001 during which responsibilities for the development of innovation were taken over by VINNOVA (*Verket för Innovationssystem*), Sweden's incumbent innovation agency at the time of writing (Sveriges Riksdag, 1999). In the beginning of its operation VINNOVA was foremost focused on raising the efficiency of the Swedish innovation system (Åström et al., 2011). For this purpose previous programs were reevaluated and several novel funding schemes were introduced. Since 2009, similar to Energimyndigheten VINNOVA's research focus is the promotion of sustainable development through the provision of innovation finance (Sveriges Riksdag, 2009). Further objectives of VINNOVA include the promotion of collaboration on the regional, national, and international level, as well as the competitiveness of Swedish companies on the world market (VINNOVA, 2022). To achieve these targets the Swedish government grants VINNOVA an annual budget of 3 billion SEK.

Even after the establishment of VINNOVA, Energimyndigheten remained a separate entity. The government motivates this as follows:

The Swedish Energy Agency is being left outside the R&D Authority and will continue to be a separate authority. The Government believes that it is important to organizationally keep energy research together with other parts of the Energy Authority's operations, since research and development work constitutes an important basis for and support for the Authority's work. (Sveriges Riksdag, 1999, p. 36)¹²

Energimyndigheten was established three years before VINNOVA, when the Swedish energy policy was reformed to promote long-term sustainable development.

It is proposed that a new energy authority be established on 1 January 1998. The majority of the authority functions in the energy field will be transferred to the energy authority. The authority will also be responsible for implementing the majority of the transition measures and for coordinating the transition work. Vattenfall AB shall, within the framework of the requirement for allocating resources for the development of new electricity production technology and thereby contribute to a Swedish electricity supply that is ecologically and economically sustainable. (Sveriges Riksdag, 1997)¹³

¹²Own translation of government bill (1999/2000:81).

¹³Own translation of government bill (1996/97:84).

Apart from establishing a new agency, the proposition specifies that funding provided for the development of energy innovation should be increased.

It is proposed that the government's efforts to develop technology for the energy system of the future be strengthened and concentrated. Energy research will be given increased resources and given a partly new focus, with emphasis on research on the energy system and international cooperation with the countries in the Baltic Sea region in particular. Support for industry-wide research and the development of new energy technology in companies and industries will be strengthened by providing additional funds to the Energy Technology Fund. An energy technology grant will be introduced to support energy technology that needs to be developed by being tested on a full scale and demonstrated with reduced risk for companies. (Sveriges Riksdag, 1997)¹⁴

4 Data and Methodology

4.1 Data sources

4.1.1 Regulation letters

The most important policy document for the analysis in this paper are regulation letters (*Regleringsbrev*). These are issued on a yearly basis by the Swedish government to all public agencies and clarify their budget and tasks for the upcoming year. Alternative sources for policy documents include the Swedish Innovation Strategy (Regeringskansliet, 2015), as well as government propositions. However, these broader strategies target multiple organization, making it harder to identify assignments to individual agencies.

Table 2: Regulation letters

Organization	Time	Obs.	Source
STU	1968–1992	23	Riksdag Library
NUTEK	1992–2001	10	Regeringskansliet, Riksdag Library
Energimyndigheten	1998–2025	28	Regeringskansliet, Ekonomistyrningsverket (2025)
VINNOVA	2001–2025	25	Regeringskansliet, Ekonomistyrningsverket (2025)
Total	1968–2025	86	

As presented in Table 2, a total of 86 regulation letters has been obtained for Sweden's main innovation agencies STU, NUTEK, and VINNOVA, as well as

¹⁴Own translation of government bill (1996/97:84).

Energimyndigheten. These documents have been screened for budget information and main funding targets.

From 2003 onwards regulation letters are publicly available on the website of the Swedish National Financial Management Authority (Ekonomistyrningsverket, 2025). Regulation letters from 1968–1997 have been collected and digitized from the Riksdag Library. Data from 1998–2002 has been provided by the Government Offices of Sweden (Regeringskansliet).

Regulation letters are quite similar across organization during a single year, but become increasingly extensive from 1998 onwards. This applies especially to regulation letter for Energimyndigheten, which contain over 20 pages outlining the government's general energy and environmental policy rather than the agency's responsibilities. Thus, from 1998 onwards merely sections on the agencies direct assignments (*uppdrag*) and financing (*finansiering*) are considered when analyzing the direction of public funding targets.

When regulation letters are directly cited in this paper they are referred to with a code consisting of the initials of the innovation agency, year, and page number. STU is referred to as ST, NUTEK as NU, VINNOVA as VI, and Energimyndigheten as EM. For example page two on the 1972 regulation letter from STU will be denoted as (ST1972:2).

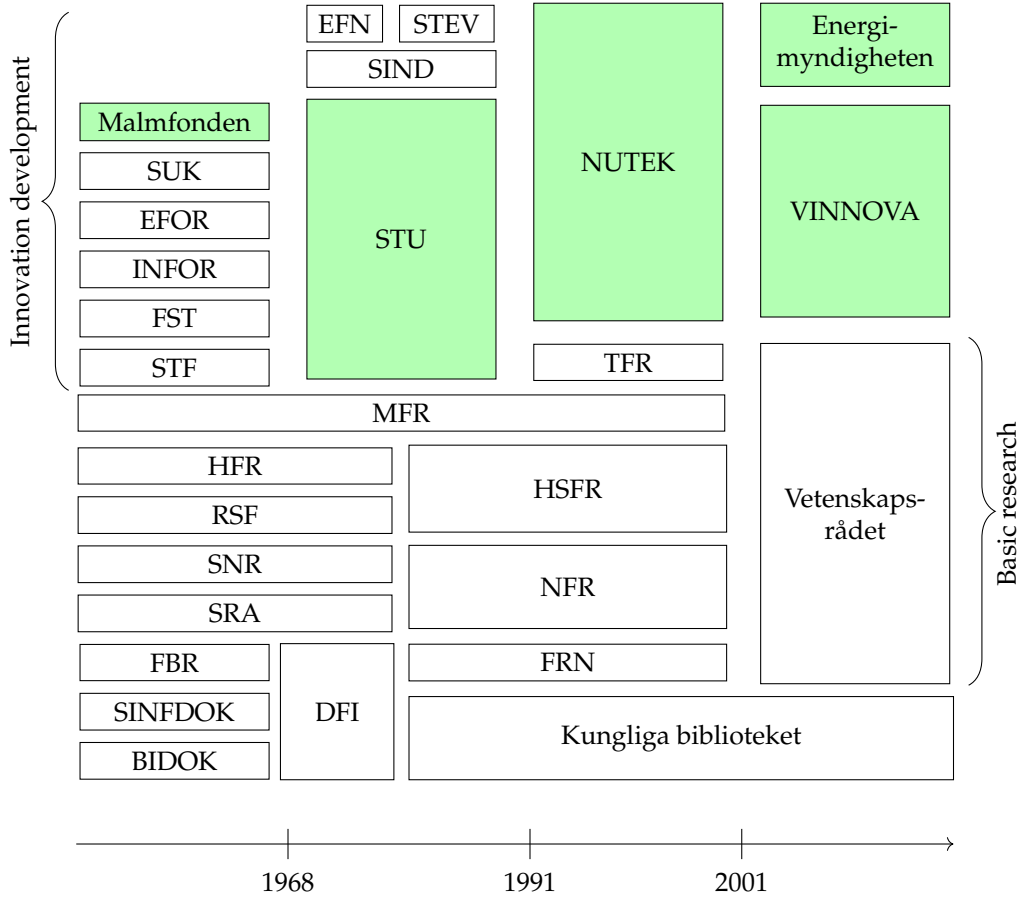
4.1.2 The Public Funding Database

Since its emergence in the first half of the 20th century, public innovation funding in Sweden has undergone frequent changes and restructuring (Åström et al., 2011). Supplementary Table 1 contains information about public funding organizations responsibilities and years of activity. For organizations involved in or in some way related to innovation development, this shift in responsibility is presented in Figure 2.

As illustrated in Figure 2, all organizations within the bracket innovation development are to some extent involved in innovation development. For the period from 1968 onwards this includes a total of 10 organizations. Notably, the main innovation agency was restructured three times over the observation period. STU (*Styrelsen för teknisk utveckling*) was the first innovation agency in Sweden, operating between 1968 and 1991. It was then replaced by NUTEK (*Närings- och teknikutvecklingsverket*), which in turn was dissolved in 2001 into VINNOVA, the incumbent Swedish Innovation Agency. Further, there exist a number of smaller agencies that were to some extent involved in innovation development. Therefore, it was necessary to combine multiple data sources to create a comprehensive database.

The final data set contains data from five different organizations, highlighted in Figure 2. These include the main innovation agencies STU, NUTEK, and

Figure 2: The public funding landscape



Note: Funding years were slightly adjusted. For example, Malmfonden was listed as a separate agency until 1971 and Energimyndigheten was established in 1998 (see Supplementary Table 1). Organizations highlighted in green are included in the Public Funding Database. These are introduced in greater detail in Section 3.3.

VINNOVA, as well as Malmfonden and Energimyndigheten. Malmfonden existed in parallel with STU from 1968–1971, it is included in the database to complement data on innovation funding during the early years on STU’s existence. Energimyndigheten took over parts of the responsibilities for the development of energy innovation from NUTEK, and remains in charge of energy innovation funding today (Energimyndigheten, 2023; Arnold and Barker, 2022). Thus, it is of central importance for the present analysis (see Section 3.3).

Table 3: Public Funding Database

	Time	Observations		Source
		Approved	Non-approved	
Malmfonden	1968–1970	106		Riksarkivet
STU	1968–1978	7,303	4,760	Riksarkivet
STINS	1979–2001	37,980	21,398	Riksarkivet
Energimyndigheten	1998–2008	6,685		Energimyndigheten
VINNOVA	2001–2009	6,382		VINNOVA
SWECRIS	2007–2023	20,544		Vetenskapsrådet (2022a)
Total	1968–2023	79,000	26,158	

Note: STINS is a digital database containing public funding projects from STU (1979–1991), as well as NUTEK (1991–2001). SWECRIS combines public funding projects from multiple organizations, however merely projects funded by VINNOVA, and Energimyndigheten are included in the present analysis.

Data on public funding projects in Sweden is obtained from the Public Funding Database, constructed by Fink and Taalbi (2024) and expanded for non-approved projects between 1968–2001 by Fink and Torregrosa-Hetland (2026). An overview of the composition of the Public Funding Database is provided in Table 3, containing over 105,000 approved and non-approved public funding projects between 1968 and 2023, from digital and archival sources.

The Public Funding Database contains project descriptions, project ids, sector information¹⁵, approval status, granted amounts, decision years, as well as project start and end dates. To ensure comparability over time all monetary values have been discounted to 2020 SEK based on inflation data from Statistics Sweden (2025).

4.1.3 SWINNO

SWINNO is a database covering 4,838 significant Swedish innovation commercialized between 1970 and 2021 (Sjöo et al., 2014; Kander et al., 2019; Torregrosa-Hetland et al., 2019; Taalbi, 2021). Innovations in SWINNO are deemed as

¹⁵Sector definitions are however inconsistent and merely available for the sub-datasets from STU, VR, SWECRIS and STINS.

significant innovation since they have been constructed based on the Literature Based Innovation Output (LBIO) approach. This approach entails the screening of trade journals, which aim to report on technological developments in their respective fields, for information on recently commercialized innovations. For each innovation, SWINNO contains a description, as well as information on innovating firms, inventors, the year of commercialization, collaborators, product codes, and funding sources.

Nonetheless, information on funding is only available for 9% of innovations, and only 6% of innovations are reported to have received public funding. Studies by Torregrosa-Hetland et al. (2019), and Fink and Taalbi (2024), suggest that public funding in SWINNO is under reported by approximately a factor of four. Therefore, this paper utilizes an updated version of the SWINNO database, which has been linked to the Public Funding Database (Fink and Taalbi, 2024; Fink and Torregrosa-Hetland, 2026).

4.2 Methodology

4.2.1 Classification of green innovation

This study applies both manual and automatic coding methods due the varying nature and number of observations across the different data sources. The classification of policy documents was conducted in fashion of traditional content analysis evaluating each case individually since their total number amounts to no more than 86. In the case of innovations and keywords, the use of automatic approaches was necessary as their number amounts to 5,000 and 157,000, respectively.

Public funding targets

Content analysis is a combination of qualitative and quantitative methods of text-based sources that was developed during World War Second by US communication researchers with the purpose to evaluate enemy propaganda. According to Prasad (2008), crucial characteristics of content analysis include the formulation of explicit rules that make results reproducible, prevent an arbitrary selection of material, and the method transferrable to similar situations. It has been adopted in policy analysis in several other fields over the past decades. One application of the methodology is to determine the direction of policy documents with regard to environmental policy and innovation development (Liao, 2018; Huang et al., 2010; Zhao et al., 2020).

Prasad (2008) provides a six-step instruction on how content analysis should be conducted. First, research questions and objectives should be formulated. Thereafter, the content for analysis should be selected. Third, content categories

should be developed. Fourth, units of analysis should be finalized. Fifth, coding should be conducted. Finally, the collected data is analyzed.

The aim of this study is to identify the direction of public support for environmental and energy innovations between 1968–2023, with a particular focus on times of economic downturn. Units of analysis are single funding targets and budget items, which are categorized based on Table 4.

Table 4: The research framework

Energy innovation	Environmental innovation
Energy efficiency	Pollution
Energy sources	Resource use

Green innovations are divided into two sub-categories, energy and environmental innovation. Energy innovations comprise all projects and targets relating to energy efficiency or which mention specific energy sources.¹⁶ Environmental innovation encompass the subcategories pollution and resource use. Pollution is considered both on the global and local level. Resource use encompasses the efficient use of material and the substitution of non-renewable products by bio-material.

Innovations and public funding projects

With nearly 5,000 innovations in SWINNO and over 100,000 public funding projects, projects have been categorized based on keywords presented in Table 5 below. This process required to account for differences in capitalization, as well as a mixture of Swedish and English project descriptions in the descriptions (particularly in the Public Funding Database). Table 4 contains the English version of the keywords used to identify green innovations. It should be noted that innovations and public funding projects can be sorted into multiple categories. In this way 1,391 innovations and 25,404 public funding projects have been identified as green innovations and public funding projects.

In order to validate the results samples of 100 innovations and 200 public funding projects were classified manually, and results compared to the results of the automatic categorization based on the keywords presented in Table 5. The results revealed that the keyword based search was highly efficient

¹⁶As in Panwar et al. (2011) only sources such as water, wind, and sunlight from which energy generation does results in nearly zero carbon emissions are considered as renewable. Nuclear energy, as well as fossil fuels are considered as non-renewable. Fossil fuel combustion releases large amounts of greenhouse gases, while nuclear generation produces radioactive waste, for which humanity yet fails to find secure storage or disposal solutions (Akpan and Akpan, 2012).

Table 5: Keywords for the classification of innovation and public funding projects

General	Energy innovation		General	Environmental innovation	
	Efficiency	Sources		Pollution	Resource use
Energy	Energy eff.	Solar	Environment	Emission	Bio material
District heat	Electricity eff.	Wind	Sustainable	Pollution	Bio-based
Fuel	Heat recovery	Biomass	Climate	Exhaust	Resource eff.
Thermal	Energy saving	Hydro	Ecological	Purification	Degradable
Electricity	Energy recovery	Biogas		Pesticide	Recycling
Battery	Smart electricity	Heat pump		Freon	Waste
		Petrol			Organic
		Nuclear			Renewable
		Oil			
		Hybrid			
		Peat			
		Coal			

when classifying green innovation and public funding projects, identifying 93% of innovations and 100% of public funding projects successfully. However, difficulty arose when attempting to automate sorting into energy innovation, environmental innovation and their subcategories. In this case, the error rate was around 60% for innovations and 50% for public funding projects.

To address this issue the sub-classification of green innovation was revised manually, which was time intensive but feasible since their total number was below 1,400. For public funding projects, manual checking was infeasible since their total number amounts to more than 25,000. Thus, public funding projects were sorted into subcategories based on transformer-based text classification. Specifically, this study uses transformers to perform zero-shot classification on how likely each label or keyword is associated to each project. The used transformer model has been trained on the Swedish language and fine-tuned for zero-shot classification (see (Vaswani et al., 2017)).¹⁷

4.2.2 Segmented interrupted time series analysis

Interrupted time-series analysis (ITS) is a common methodology for assessing the impact of economic crises on health and financial outcomes (Crookes et al., 2020; Turner et al., 2021). The idea behind ITS is to decompose the impact of an event on an outcome variable into three components: the initial pre-intervention slope, the level change around interruption, and the post-intervention slope. In this paper it is applied to estimate the impact of major economic crises on the

¹⁷A big thank you goes to Andy Oertel for helping with the implementation of this method.

direction of public innovation funding.

The ITS regression model is presented in equation 1. The outcome variable *Green* is the fraction of public funding for green innovation during year t . As discussed in Section 3.1, Sweden experienced three major economic crises k over the study period, all of which are contained in the regression model. Observations dating after the outbreak of crisis k are indicated by the dummy variable $Post_k$. Trend changes are captured by $Trend_k$, ε_t is the error term.

$$Green_t = \beta_0 + \beta_1 t + \sum_k (\beta_{2k} Post_{kt} + \beta_{3k} Trend_{kt}) + \varepsilon_t \quad k \in \{1973, 1990, 2008\} \quad (1)$$

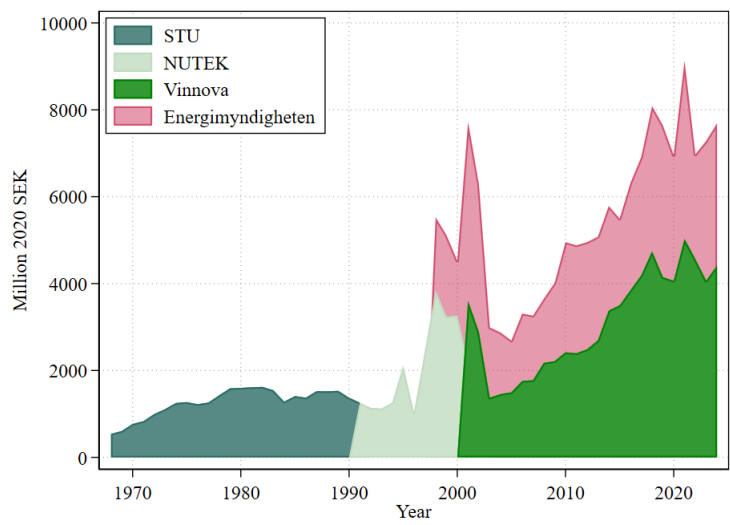
There exist models to estimate ITS, this paper will focus on ordinary least square model (OLS) with Newey-West standard errors (NW), Prais-Winsten generalized least squares (PW), and the auto-regressive integrated moving average (ARIMA). The purpose of NW is to adjust standard errors for autocorrelation (Newey and West, 1986). PW are extended OLS where the independence assumption across observations is relaxed (Prais and Winsten, 1954). ARIMA includes previous values of the independent variable and errors in the regression modes (Nelson, 1998). These alternative estimation models are compared in greater detail in Turner et al. (2021).

4.3 Summary statistics

The total budget of Swedish innovation agencies according to the regulation letters is presented in Figure 3. From 1998 onwards the budget of Energimyndigheten is stacked over that of the main innovation agency. Budgets of public funding agencies have increased sevenfold, between 1995 and 2001, where it amounted to approximately 7 billion SEK. After the transition towards VINNOVA was completed budgets returned to 1990s levels and grew steadily to around 4 billion SEK for VINNOVA and 3 billion for Energimyndigheten, respectively.

Table 6 presents the number of public funding projects and innovations classified as green innovation, which constitute a total of 962 innovations, corresponding to 20% of innovations in SWINNO. Of these 711 are classified as energy and 360 as environmental innovation. Energy and environmental innovation do not add up to 962 since innovations can fall into both categories simultaneously. This applies to 109 innovations.

Figure 3: Total budget granted to Swedish innovation agencies, 1968–2025 (Million 2020 SEK)



Source: Regulation letters

Table 6: Energy and environmental innovation

	Energy innovation			Environmental innovation		
	Source	Efficiency	Total	Resource	Pollution	Total
PFD	13,646	14,765	20,023	17,013	8,984	19,576
SWINNO	252	315	711	168	198	360

5 Results

5.1 Direction of public funding

Regulation letters contained references to energy and environmental innovation for most years during the observation period, especially during the latter half. However, the direction of funding targets shifts over time and instructions to innovation agencies are increasingly specified. Until the late 1990s, instructions in regulation letters mainly contained instructions to support environmental and energy innovations in general. Energy efficiency was only specifically mentioned in 1978 and 1979, before the establishment of Energimyndigheten two decades later. Also, support for renewable energy technologies was not mentioned a single time before 1998. Innovation agencies were only specifi-

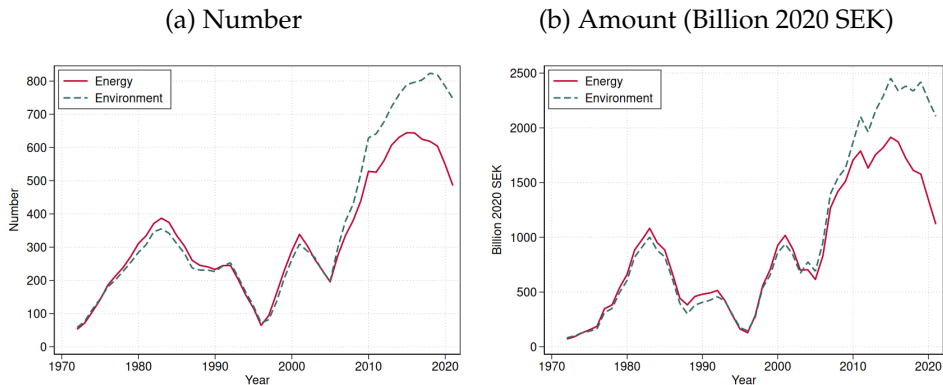
cally tasked with the support to nuclear generation¹⁸, and fossil fuel use and extraction¹⁹.

The first time a regulation letter specifically instructs an innovation agency to develop a certain type of environmental innovation can be found in 1979. In STU's regulation letter from that year, it was instructed to allocate 2.2 million SEK to improve ventilated air quality (ST1979:35).

Regulation letters addressed to Energimyndigheten outline support for environmental and energy innovations during every single year since its foundation in 1998, marking a breaking point in support for green innovation. The regulation letter to Energimyndigheten in 1998, specifies that it should support efforts to increase energy efficiency and research into renewable energy technologies. Research into biofuels is of special attention during this period, receiving a budget of 90 million SEK, a third of the Energimyndigheten's total budget for energy related research (EM1998:20).

Trends in the number of green innovation, and total granted amounts are presented in Figure 4. Both indicators have nearly consistently increased over the study period. The only major exception from this rule are the mid-1990s, when public funding experiences massive cuts in the aftermath of the Scandinavian Banking Crisis.

Figure 4: Green public funding projects, 1970–2021 (5-year moving average)



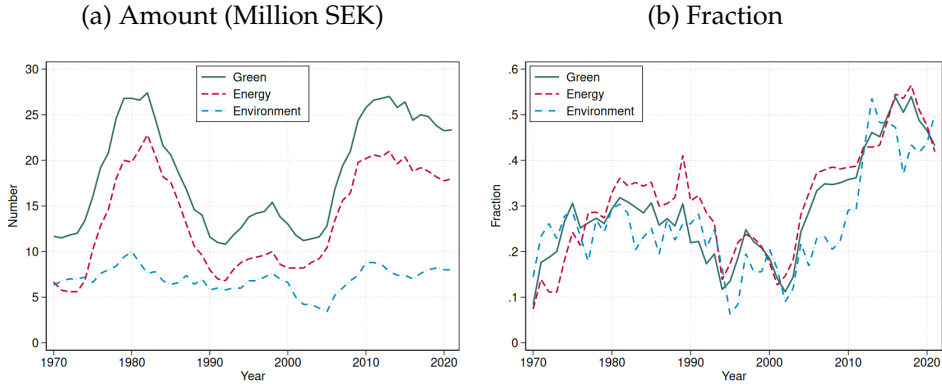
Public funding shares for green innovations are presented in Figure 5. As in previous parts of the analysis, results are distinguished between environmental and energy innovation. The number and share of energy innovation varies significantly during the observation period. While there are less than 10 energy

¹⁸Out of the 7.2 million SEK for energy technology 3 million SEK should be used for uranium enrichment (STU1973:17)

¹⁹3 million SEK for offshore technology (STU1978:34); 4.4 million SEK for offshore extraction of oil and gas (STU1979:35).

innovations annually in the early 1970s and 1990s, their number rises to over 20 in the early 1980s and the mid-2000s. This can most likely be accounted to the outbreak of the oil crisis in 1973 and rising oil demand from China after 2000 (see Fink and Taalbi (2024)).

Figure 5: Funding for green innovation, 1970–2021 (5-year moving average)



For environmental innovations trends are far more stable over time, their number remain around 7 throughout the study period while their share doubles to 50% around 2010.

5.2 Responsibility for green innovation

Responsibility for the development of green innovation are outlined in government bills and regulation letters. Moreover, regulation letters contain more specific instructions regarding the types of projects that agencies should support. From government bills we can derive that STU was not founded with the specific purpose to promote the development of green innovation but rather for applied research in general (Sveriges Riksdag, 1968). This was different for its both successors and Energimyndigheten.

NUTEK was specifically instructed to promote energy efficiency and growth of the overall energy supply (Sveriges Riksdag, 1991). Further, *the agency shall meet the environmental objectives set by the Government.*²⁰ Thus, NUTEK was from its foundation responsible for the development of both types of green innovation. Similarly, VINNOVA was established with the purpose to promote sustainable development in general, while Energimyndigheten should foster sustainability through its support for energy innovation (Sveriges Riksdag, 1999, 1997).

²⁰Own translation of government bill SFS(1991:960)

Despite the fact that green innovation were not specifically named in the government bill announcing the establishment of STU, regulation letter from later years of its existence contain references towards the development of green innovation. Energy and environmental technology are among the areas of need (*behovsområden*) established in 1972.

Surprisingly, NUTEK's regulation letter do not mention environmental innovation specifically for the first seven years of its existence despite the organization being established with instructions to comply with environmental targets set by the government (Sveriges Riksdag, 1991).

The regulation letter to Energimyndigheten in 1998, specifies that it should support efforts to increase energy efficiency and research into renewable energy technologies (EM1998:20). In NUTEK's regulation letter from the same year support for energy innovation is not mentioned a single time (NU1998:1-28). Thus, the two agencies were designed as complementary providers of innovation funding.

However, this complementarity was no longer maintained when VINNOVA was established in 2001. 10% out of VINNOVA's 1 billion SEK budget were dedicated to the support for energy innovation, despite the existence of a specific agency for the sector. Furthermore, VINNOVA had instruction to foster the development of environmental friendly transportation, improved resource and energy efficiency with 15% of its annual budget (VI2001:10). These were similar to directions received by Energimyndigheten during the same year. Namely, the support for environmental friendly transportation and improved energy efficiency (EM2001:7).

This development is concerning in the light of the discussion on efficient public funding allocation (Handley, 2008; Tetlak et al., 2025). In case that multiple funding agencies are responsible for supporting green innovation, a lack of coordination can lead to a sub-optimal synergies across public funding projects and harm the coordinating function of innovation agencies. Further, innovating firms might struggle to identify the innovation agencies most suited to support their innovation projects, forcing firms to apply multiple times for the same projects in the presence of competition and budget constraints.

Over the following years the division of responsibility became more pronounced. Support for energy innovation was to an increasing extent directed towards Energimyndigheten, while VINNOVA focused on environmental innovation outside the energy sector. Energimyndigheten's regulation letters from the late 2000s state that the agency should contribute to sustainable development through their investments into renewable energy technology. An example from the 2009 regulation letter:

The appropriation item is subject to the Ordinance (2003:564) on contributions to measures for an efficient and environmentally friendly energy supply in the parts that

*relate to technology procurement and development before the product is introduced on the market, as far as measures that promote the expansion of district heating networks and new energy-efficient technology and the use of existing energy-efficient products are concerned (EM2009:12).*²¹

VINNOVA on the other hand received clear instructions to promote sustainable development outside of the provision of promoting energy efficiency and renewable energy sources. For example, VINNOVA should promote the marine environment in the Baltic sea region and conduct pollution measurements (VI2010:4).

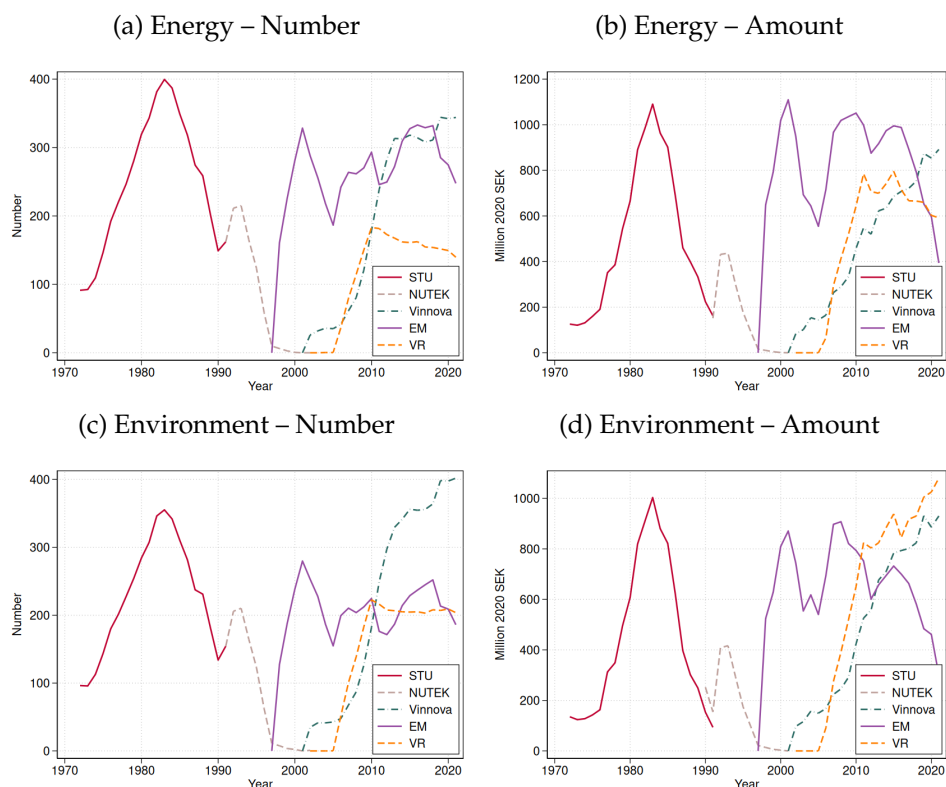
To further investigate how responsibilities for the development of green innovations are distributed across innovation agencies and time, the number and amounts of granted public funding projects by innovation agencies and sub-types of green innovation are presented in Figure 6. Overall patterns are similar for both types of green public funding projects. Funding picked up rapidly during the 1970s, most likely in reaction to the oil crisis. Thereafter, interest in green innovation declines rapidly, particularly when budgets of innovation agencies collapsed during the mid-1990s. Funding from NUTEK dropped close to zero. During its low point in 1999 merely two energy and environmental public funding projects were funded by NUTEK during the whole year, compared to 454 energy and 394 environmental public funding projects approved by STU in 1982. With the establishment of Energimyndigheten funding for green innovation picked up rapidly. By 2001 funding for energy innovation increased to over 1 billion SEK, and close to that number for environmental innovation.

As investigated in the previous sub-section, responsibilities to promote the development of green innovation were split between VINNOVA and Energimyndigheten during the early 2000s. Energimyndigheten should as its name suggest focus on technical development within the energy sector, while VINNOVA supports general environmental innovation. Nonetheless, the number projects funded by the two organizations is around 300 since around 2010, and the money spent by VINNOVA for energy related projects has been exceeding funding by Energimyndigheten since 2015.

No similar overlap in support for environmental public funding projects can be observed since the assignment of responsibility for the development of environmental innovation to VINNOVA. By 2021, VINNOVA funded twice as many environmental projects with a three times bigger budget than Energimyndigheten. However, also in this area the division of responsibilities is becoming less pronounced. The share of environmental innovation receiving funding from Energimyndigheten has more than doubled around 2015, and remained stable at around 20% until the end of the observation period.

²¹Own translation

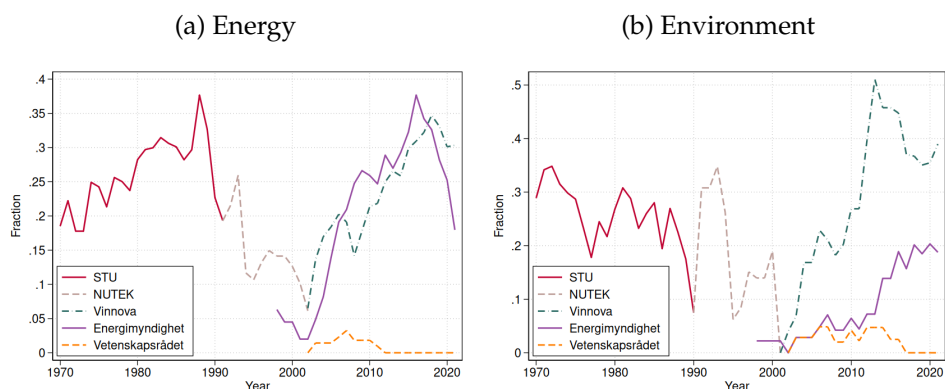
Figure 6: Funders of green public funding projects, 1970–2021 (5-year moving average)



To address the question who funds which innovations, public funding shares have been broken down by public funding agency in Figure 7. As suggested in the analysis of the regulation letters, a division of responsibilities emerges between Energimyndigheten and VINNOVA in the early 2000s, where Energimyndigheten focuses nearly exclusively on energy innovation, while environmental innovation is primarily funded by VINNOVA. However, when looking at granted public funding projects, VINNOVA remains a central actor in the actual funding of energy innovation despite regulation letters putting little emphasis on supporting energy innovation specifically.

One explanation for this is frequent joint financing of VINNOVA and Energimyndigheten for energy innovation projects. Since 2001, 38 or 11.2% of all energy innovations in SWINNO were jointly funded by VINNOVA and Energimyndigheten. Among environmental innovation this applies to 10 innovations or 7.2%.

Figure 7: Funders of green innovations, 1970–2021 (5-year moving average)



5.3 Impact of economic crises

This sub-section investigates the question whether economic crisis are associated with a backsliding in green innovation funding. A visual analysis of Figures 4 and 5 suggests that the impact of economic crises is not uniform over the study periods. While the number and budget for granted projects plummeted in the aftermath of the Scandinavian Banking Crisis, the oil crises and the Great Financial Crisis saw instead a rise in green innovation funding. This is further studies with help of ITS. The results are presented in Table 7. Newey-West (NW), Prais-Winsten (PW) and ARIMA estimates are calculated for each event separately. Funded amounts are presented as logged variables.

Table 7: ITS results – Funding for green innovation (PFD)

	First Oil Crisis			Scandinavian Banking Crisis			Great Financial Crisis		
	NW	PW	ARIMA	NW	PW	ARIMA	NW	PW	ARIMA
Year	0.001 (0.445)	0.001 (0.586)	0.001 (0.709)	0.011** (0.048)	0.011 (0.121)	0.011 (0.227)	0.006** (0.024)	0.005* (0.059)	0.005** (0.029)
Post 1973	0.189*** (0.000)	0.113 (0.244)	0.114 (0.362)						
Post 1990				0.031 (0.711)	0.048 (0.551)	0.047 (0.657)			
Trend 1990				-0.014** (0.018)	-0.014* (0.068)	-0.014 (0.218)			
Post 2008							-0.113** (0.049)	-0.044 (0.623)	-0.043 (0.850)
Trend 2008							-0.007** (0.013)	-0.012 (0.256)	-0.012 (0.786)
Constant	-1.771 (0.458)	-2.015 (0.609)	-2.005 (0.726)	-21.248** (0.050)	-20.709 (0.125)	-20.709 (0.232)	-10.702** (0.027)	-9.912* (0.066)	-9.904** (0.034)
AR(1)			0.554*** (0.000)			0.478*** (0.000)			0.490*** (0.000)
σ			0.090*** (0.000)			0.087*** (0.000)			0.089*** (0.000)
Observations	50	50	50	50	50	50	50	50	50
R-sq		.			0.059			0.021	

Most Newey-West estimates are significant, indicating a positive level change in 1973, a negative level change in 1990, and negative level and trend changes after the outbreak of the great financial crisis. However, merely the negative trend shift is confirmed by the Prais-Winsten specification. ARIMA estimates are in all cases insignificant due to large standard errors, despite estimated effects being the same.

The large standard errors of ARIMA estimates detected here are in line with the findings of Turner et al. (2021). Therefore, they are not interpreted as an indicator that the trend change in 1990 is insignificant. Newey-West estimates on the other hand are known for making estimates appear more significant than they actually are (Andrews, 1991; Gow et al., 2010). Therefore, merely the negative trend change in 1990 is interpreted as a significant result.

To calculate the treatment effect we need to consider the pre-treatment slope, specified in the *Year*-estimate and subtract the *Trend*-estimate, thus: $0.011 - 0.014 = -0.003$. In words, after the outbreak of the Scandinavian Banking Crisis, logged funded amounts turn negative, falling by 0.3% annually.

The results that merely the Scandinavian Banking Crisis is associated with a significant drop in public support for green innovation comes rather surprising, as they differ from previous research on environmental attitudes and policy during the Global Financial Crisis. The majorities of these studies detects a negative connection between the two (Geels, 2013; Andersson and Arvidsson, 2024).

With an exception for the 1990s crisis, public funding for green innovation shows counter-cyclical tendencies. This findings is in line with Pellens et al. (2024), who detect increased public support for applied research during economic crises among innovation leaders (including Sweden). In connection with findings of O'Callaghan et al. (2022), this is a promising development, since the development of green innovation has been linked to greater increases in employment and overall economic growth compared to non-green investment.

6 Discussion and concluding remarks

This paper analyzes long-term trends in the directionality of public innovation funding in Sweden with a particular focus on economic downturns. The paper draws on three data sources, regulation letters to public funding agencies, a database over public innovation funding in Sweden, and a database over significant innovation in Sweden are utilized.

To what extent has public innovation funding been directed towards green innovation? Historically the Swedish government did not provide much di-

rection to innovation agencies on which technologies to focus. Within larger areas of need innovation agencies were free to make calls of judgment on which technologies to promote. This changed during the late 1990s. Starting with the establishment of Energimyndigheten, regulation letters clearly outline which kind of green innovation should be promoted. It lists not only prioritized technologies but also how much funding should be allocated to each area. Public support for energy and environmental innovation varied also in terms of public funding projects and support for innovation outputs. However, energy innovation funding is far more volatile compared to environmental innovation, and closely connected to economic incentives. This changes only in the 2010s when public support for energy innovation despite of falling energy prices, and is in line with finding of Zhang et al. (2021) and Fink and Taalbi (2024).

How have responsibilities shifted across agencies and time? Support for green innovation was handled by main innovation agencies, and they were responsible for both subtypes (energy and environmental technology) until the establishment of Energimyndigheten in 1998. From thereon Energimyndigheten was responsible for promoting the development of energy related technology, while main innovation agencies were instructed to promote non-energy environmental innovation.

Nonetheless, regulation letter and ex-post funding data suggest that areas of responsibility between Energimyndigheten are overlapping. For environmental innovation this applies mainly to the early 2000s, while both agencies are actively involved in the funding of energy innovation. This is concerning in the light of the literature on effective direction of public funding, pointing to a negative relationship between effective allocation of public funds and overlapping areas of responsibility (Handley, 2008; Tetlak et al., 2025).

Have economic crises been associated with a backsliding towards conventional technologies? The question whether economic crises are associated with a reduction in public support for green innovation has been addressed by combining a visual inspection of the data and ITS regression. In both cases a negative impact on support green innovation is observed after the outbreak of the Scandinavian Banking Crisis in 1990. Neither the First Oil Crisis nor the Great Financial Crisis had a similar effect. The visual inspection suggests rather a rise in public support for green innovation around this time. However, support from the regression analysis for this finding is limited as estimates are only significant under one of three ITS model specifications.

This finding stands in contrast to findings on the impact of economic crisis on environmental behavior and investment (Geels, 2013; Andersson and Arvidsson,

2024).

Take aways Support for green innovation has nearly continuously grown over the observation period, and has been very stable for environmental innovation. However, public energy innovation funding has been closely linked to economic incentives, thus showing pro-cyclical tendencies until recent years. This is concerning since the need for public funding is particularly high in the energy sector, while it is also of central importance to climate change mitigation efforts. Despite its long-term commitment to sustainable development and public support for applied research, the Swedish government did not provide much direction to innovation agencies on which technologies to focus. Within larger areas of need innovation agencies were free to make calls of judgment on which technologies to promote, while they have provided very clear instructions since the late 1990s.

Interesting in this context was also that while there exists in theory a clear division of responsibilities for the support of different types of green innovation, this is not translated into practice. This applies especially energy innovation funding, which is towards the end of the observation period dominated by Sweden's main innovation agency VINNOVA, despite the existence of a specific agency for the Energy sector. This might result in inefficiencies in case that firms have to apply to multiple agencies in order to improve success chances. Moreover, in case of waste of time and financial resources.

Finally, even in countries with substantial public support for a green transformation, severe economic downturns are associated with a decreasing focus on green technology. Nonetheless, a significant correlation was merely detected in connection with the most severe crisis faced by Sweden over the past 50 years.

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Appendix

Supplementary Table 1: Overview of Swedish public funding bodies

Swedish name	Acronym	Start	End	Information	Source
Main innovation agencies					
Styrelsen för Teknisk Utveckling	STU	1968	1991	Promotion of collaboration between academia and industries; focus on "economic areas of special interest", new focus on applied research	Perez Vico and Hallonsten (2019); Åström et al. (2011)
Närings- och teknikutvecklingsverket	NUTEK	1991	2000	Fusion of STU, Industriverket, and Statens energiverket; ontribute to long-term development of the industrial and energy secotr	Perez Vico and Hallonsten (2019); Åström et al. (2011), Riksarkivet (2022)
Sveriges innovationsmyndighet	VINNOVA	2001		Promotion of sustainable development through the provision of innovation finance	VINNOVA (2022); Sveriges Riksdag (2009)
Related agencies					
Svensk uppfinnarkontoret	SUK	1947	1968	General support for inventors, check inventions, informations on patenting	Riksarkivet (2022)
Malmfonden		1961	1971	Support research and development in the scientific and technical sector with industrial connections; Projects were transferred to the STU after its establishment in 1968	Riksarkivet (2022)
Stiftelsen för exploatering av forskningsresultat	Efor	1963	1968	Mediation of research results	Riksarkivet (2022)
Institutet för nyttiggörande av forskningsresultat	INFOR	1964	1968	Further development of research findings and inventions for industrial use	Riksarkivet (2022)
Fond för skeppsteknisk forskning	FST	1970	1978	Marine technology	Riksarkivet (2022)
Statens Industriverket	SIND	1973	1991	Promote industrial development and finance regionalpolitical development	Nationalencyklopedin (2023)
Energy related agencies					
Statens råd för atomforskning		1950	1976	Nuclear research	Riksarkivet (2022)
Värmeforsk		1968	2015	Finance and direct research in the fields of combustion, heat and environmental technology	Nationalencyklopedin (2023)
Energiforskningsnämnden	EFN	1982	1990	Long-term energy related research; function taken over by Statens energiverk in 1990	Nationalencyklopedin (2023)
Statens Energiverket	STEV	1983	1991	Administration of Swedish energy policy	Nationalencyklopedin (2023)
Energimyndigheten		1998		Promote transitions towards a sustainable energy system, research in fuel, renewable energy sources, green technology and international climate collaboration	Energimyndigheten (2023)
Elforsk		1993	2015	Research and development company of Swedish electrical companies	Energiforsk (2023)
Fjärrsyn		2006	2015	Research on district heating	Energiforsk (2023)
Svenskt Gastekniskt Center	SGC	1990	2015	Promote research on renewable gas from decomposition and gasification	SGC (2023)
Energiforsk		2015		Coordination and promotion of energy research	Energiforsk (2023)
Research councils					
Vetenskapsrådet	VR	2000		Largest governmental research funding body in Sweden with a budget of almost 8 billion, promotion of research in all scientific areas	Vetenskapsrådet (2022b); Sveriges Riksdag (2000), Nationalencyklopedin (2023)
Statens kommitté för byggnadsforskning		1942	1953	Building sector	Riksarkivet (2022)
Statens tekniska forskningsråd		1942	1968	Technical research finance, no support for applied research	Riksarkivet (2022)
Medicinska forskningsrådet	MFR	1945	2000	General and militaristic medical research	Riksarkivet (2022)
Skogs- och jordbruksforskningsrådet	SJFR	1945	2000	Research in agriculture and forestry	Riksarkivet (2022), Nationalencyklopedin (2023)
Statens naturvetenskapliga forskningsråd		1946	1976	Support scientific publications	Riksarkivet (2022)
Statens råd för samhällsforskning		1947	1976	Social science research	Riksarkivet (2022)

Statens nämnd för byggnadsforskning		1953	1960	Building sector	Riksarkivet (2022)
Statens humanistisk forskningsråd		1959	1976	Humanistic research	Riksarkivet (2022)
Byggeforskningsrådet	BFR	1960	2000	Promote reasearch in community planning and the building sector	Byggeforskningsrådet (2016), Riksarkivet (2022)
Humanistisk-samhällsvetenskapliga forskningsrådet	HSFR	1976	2000	Promote and initiate research in social science, humanities, law, and religious studies	Nationalencyklopedin (2023), Vetenskaprådet (2022b)
Naturvetenskapliga forskningsrådet	NFR	1976	2000	Natural science and mathematic basic research	Nationalencyklopedin (2023), Vetenskaprådet (2022b)
Forskningsrådsnämnden	FRN	1977	2001	Support research and information on research; promote collaboration between research institutions	Nationalencyklopedin (2023)
Teknikvetenskapliga forskningsrådet	TFR	1990	2000	Technologic base research and research training; preference for projects promoting international collaboration	Riksarkivet (2022)
Forskningsrådet för hälsa, arbetsliv och välfärd	FORTE	2000		Research on health, worklife and welfare, annual budget of 800 million SEK	FORTE (2023)
Statligt forskningsråd för hållbar utveckling	FORMAS	2009		Research and innovation funding in environmental, agricultural science, spatial planning; Aiding Sweden in its effort to achieve the environmental targets	FORMAS (2023); Regeringskansliet (2009)

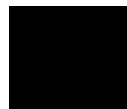
Further funding bodies contained in SWECRIS

1953 års fond		1953	1964	Support of poor students at Lund and Malmö univeristy	Riksarkivet (2022)
Hjärt-lungfonden			1904	Founded as Swedish National Anti-tuberculosis association. Today general research in the field of cardio-vascular diseases	Hjärt-Lungfonden (2023)
Ragnars Söderbergs Stiftelse			1960	Early career support for scientists in economics, medicine, and law	Ragnar Söderbergs Stiftelse (2023)
Familjen Kamprads Stiftelse			2011	Entrepreneurship, sustainability, and elderly care	Familjen Kamprad Stiftelse (2026)
KK-Stiftelsen			1994	Foster Sweden's academic competitiveness, academia-industry collaborations	KK-Stiftelsen (2026)
Naturvårdsverket			1994	Environmental protection	Naturvårdsverket (2026)
Statens Geotekniska Institut	SIG	1944		Promote geotechnical research in Sweden. Its research is of special importance for the construction sector.	SGI (2023)
Östersjöstiftelsen			1994	Development in Eastern Europe and the Baltic region	Östersjöstiftelsen (2023)
Karolinska Institutet			1810	Medical education and research	Karolinska Institutet (2026)
Institutet för arbetsmarknads- och utbildningspolitisk utvärdering	IFAU	1997		Research on labor market and education policy, annual budget of 6 million SEK	IFAU (2023)
Rymdstyrelsen	SNSB	1992		Space research and space applications	Wormbs and Källstrand (2007)
Stiftelsen Riksbankens Jubileumsfond	RJ	1964		Promotion and support of humanistic and social science research; Increasing focus on supporting of long term projects and international collaborations	Riksbankens Jubileumsfond (2017)

Other agencies

Forskningsbiblioteksrådet	FBR	1965	1979	Provide information for research and development	Riksarkivet (2022), Nationalencyklopedin (2023)
Kungliga biblioteket			1968	Preservation and digitization of information in written, audio, and virtual form; Partially responsible for DFIs operations since 1988	Nationalencyklopedin (2023)
Statens råd för vetenskaplig information och dokumentation	SINFDOK	1968	1979	Provide information for research and development	Nationalencyklopedin (2023), Riksarkivet (2022)
Delegation för rymdverksamheten	SBSA	1972	1992	Space research and space applications	Wormbs and Källstrand (2007)
Biblioteks- och dokumentationssamverkanskommittén	BIDOK	1975	1979	Provide information for research and development	Riksarkivet (2022), Nationalencyklopedin (2023)
Delegationen för vetenskaplig och teknisk informationsförsörjning	DFI	1979	1988	Provide information for research and development	Riksarkivet (2022), Nationalencyklopedin (2023)

Paper II



Picking winners and directions? Public innovation funding in Sweden, 1970-2021.

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Abstract

In the face of climate change, governments are scaling up public investments in mitigation efforts and green technologies. However, critics question the ability of public funding agencies to promote the most promising innovations. This paper contributes to this debate by presenting a long-term database, that directly links Swedish innovations to public funding between 1970 and 2021. We use logistic regression models to analyze what innovations are most likely to receive public funding. A remarkable 43% of the most radical innovations relied on public funding. Likewise, energy innovations are more likely to rely on public funding, especially radical energy innovation. A shift in directionality towards renewable energy innovation can be observed from 2000 onwards. Contrary to received notions that governments are unable to pick winners, our findings highlight that public spending in Sweden has shaped market conditions, aptly funding the most radical innovations, and played a role in climate change mitigation efforts by supporting the development of renewable energy technologies. Meanwhile, our analysis also highlights a need to strengthen the consistency of support for energy innovation and to enhance funding for early-stage innovation development.

Keywords: Public funding, innovation, sustainability, energy innovation, renewable energy

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1 Introduction

The mitigation of climate change is without doubt among the biggest challenges faced by humanity (IPCC, 2018; Shmelev and Speck, 2018; Fouquet and Pearson, 2012). To avoid global heating by more than 2°C, a rapid reduction in greenhouse gas emissions must be achieved over the next three decades (Lamboll et al., 2023). Reducing fossil fuel combustion is of central importance for the achievement of the climate targets, as it is responsible for about 80% of global greenhouse gas emissions (Akpan and Akpan, 2012).

To counter these challenges, ambitious policy targets, such as the Mission Innovation initiative and the EU Green Deal, have been set to accelerate government spending on clean energy research and innovation. While industrial policy was long regarded with skepticism, it has recently moved to the forefront of government rhetoric (Evenett et al., 2024) and is viewed increasingly more favorably in academic literature (Juhász et al., 2024). However, there are still debates surrounding the design of public innovation policy.

Public involvement in innovation activity has come under fire for different reasons. The classical critique is that governments are argued to be unable to effectively *pick winners* or fund promising innovations since they lack sufficient information on firms' internal affairs. Therefore, public funding may be inefficient, and more likely to fail than privately funded projects (Pack and Saggi, 2006; Helm, 2010; Lerner, 2009; McKenzie, 2017). A second line of critique is that the provision of public support encourages *rent-seeking* behavior. Firms in the targeted sector will try to maximize subsidies, while minimizing the amount of investment that is required to obtain them. Examples of highly publicized failures include the large-scale public support for Solyndra in the US and Northvolt in Sweden (Caprotti, 2017; Näsman et al., 2026). Owing in part to risks of failures, many researchers instead favor carbon taxes. Instead of public actors, winners are instead picked by markets via a bottom-up process, in line with carbon emission targets (Nordhaus, 1993; Cramton et al., 2017).

A different line of literature has argued that there is *too little* or too inconsistent public funding of research and innovation to overcome carbon lock-in (Rodrik, 2014). Leading economists argue that efficient climate policy cannot rely only on carbon taxes but requires direct subsidies (Aghion et al., 2019; Acemoglu et al., 2016). Despite efforts only a moderate rise in R&D funding has occurred since 2015 (Chong, 2022) and in many countries public engagement in energy research has been of the character of temporary bursts in response to oil prices (Zhang et al., 2021). To facilitate a successful transition towards renewable sources, research calls for increased public support for energy innovations (Fouquet and Pearson, 2012; Gallagher et al., 2012; Wang et al., 2024), alongside calls for governments to move towards proactive market-shaping approaches

(Mazzucato et al., 2015; Mazzucato, 2022; Wanzenböck et al., 2020).

This study aims to understand the role of public funding in Sweden, one of the world's leading innovation economies (Dutta et al., 2023). Rather than inquiring about the effects of public funding (additionality), we take interest in whether and to what extent public funding is associated with types of innovation that are “underprovided” by market mechanisms. We argue that the rationale for public funding is strongest for radical innovation, early-stage projects, small-firm innovations and technologies that break with fossil lock-in, and investigate to what extent public funding has consistently funded such technology.

Empirically, this paper departs from noting that progress in the debates about the design of public innovation funding has so far been impeded by data availability. Pless et al. (2020) call for the creation of long-term energy innovation database that comprises information on both innovation inputs, innovation outputs, and their direction. In this paper, *direction* refers to technologies that contribute to climate change mitigation efforts, such as renewable energy technology and energy saving technologies.

To this end, we constructed, to our best knowledge, the first database that directly links public funding projects to actual innovation outputs. A micro-data approach allows us to analyze fine-grained patterns of public funding. While many studies on public funding use proxies for innovation such as patents or publications (Fleming et al., 2019; Wang et al., 2024, see also overview in Jugend et al., 2020), our analysis focuses on commercialized innovation output (Taalbi et al., 2024, see also van der Have and Deschryvere, 2026).

The database consists of 4,838 significant Swedish innovations commercialized between 1970 and 2021 (Sjöö et al., 2014; Kander et al., 2019) that have been linked to 121,501 public funding projects. We use a logistic regression model to analyze what types of innovations are most likely to receive public funding. Special focus is placed on the questions of whether energy and radical innovations are generally more likely to receive public support and whether public funding bodies specifically target the emergence of renewable and energy saving technologies.

Sweden's public funding system is of broad interest for several reasons. Sweden is considered one of the world's most innovative economies. It ranked third in the 2023 Global Innovation Index, second in the 2023 European Innovation Scoreboard, and it had the highest investment in research and development (R&D) within the EU in 2022 (Dutta et al., 2023; EU, 2023; Eurostat, 2022). Moreover, it was one of the first countries to establish a second generation innovation agency STU (*Styrelsen för teknisk utveckling*) in 1968, that actively promoted applied research (Weinberger, 1997; Arnold and Barker, 2022). Furthermore, Sweden is considered a pioneer in environmental policy. It hosted the first UN climate conference in 1972 and reported the lowest greenhouse

gas emission per capita among EU members in 2019 (Shmelev and Speck, 2018; Larsson Heidenblad, 2021).

While the here-presented analysis is not aiming to address whether public innovation funding has causal effects, it produces new insights into to what extent public funding has been able to support radical innovation and sustainable transitions and whether this support is consistent over time. The results of this study suggest that public innovation funding in general, and for the energy sector in particular, has been allocated towards the most promising technologies. Radical innovations are consistently most likely to receive public support, exceeding the likelihood of incremental innovations by a factor of 2.64. Furthermore, public funding has been increasingly directed towards renewable energy innovations. Since 2000 they are 2.5 times as likely to receive public support compared to non-renewable technologies, marking a break in Swedish innovation policy and the importance of public funding agencies for climate change mitigation efforts. Meanwhile, our analysis also illuminates challenges to the design of public funding instruments. Our results suggest that there may be challenges in funding early-stage innovation and that public funding of energy innovation has not always been consistent over time.

The remainder of this paper is structured as follows: The second section summarizes previous research on public innovation funding and identifies areas where of public funding has a strong rationale. Section 3 provides background information on public funding for applied research. The fourth section contained information on data sources and methodology. In the following regression section, the main empirical results as well as several robustness checks are presented. The final section summarizes and discusses the studies main conclusions and outlines future research possibilities.

2 Public funding of innovation

This study aims to understand the role of public funding in the Swedish innovation system. Our approach is shaped by the emergence of a new framing of innovation policy that rather than addressing market failures or national competitiveness stresses addressing grand challenges such as climate change (Schot and Steinmueller, 2018; Mazzucato, 2018). Rather than inquiring about the causal effects of public funding on R&D, our main interest lies in understanding more broadly what public funding does and to what extent public funding is associated with types of innovation and directions that are “underprovided” by market mechanisms. We argue the rationale for public funding is strongest for radical innovations, early-stage projects and innovations by small firms, and technologies that help overcome fossil lock-in. Below we review the main

arguments and critiques.

Public funding of innovation is often justified on the grounds that socially valuable innovations are systematically underprovided by private actors. Private interests do not take into account positive knowledge externalities (Arrow, 1962; Nelson, 1959) and underinvest in projects with high risk or long time horizons (Hall and Lerner, 2010; Warwick and Nolan, 2014). Radical innovation is characterized by fundamental uncertainty and novel technologies may take several years until reaching maturity during which they do not create revenues for the innovating firm (Alchian, 1950; Kline, 1985).

In other words, innovation in general, but radical innovation in particular, is likely to be underprovided. For such reasons, public actors have been argued to play an important role in developing or supporting high-risk technologies and technologies that require long-term funding (Fouquet and Pearson, 2012; Mazzucato et al., 2015; Mazzucato and Semieniuk, 2018, 2017; Wang et al., 2024). Governments have access to far greater funds than most companies allowing them to provide long-term finance and constructing complementary infrastructure without running the risk of bankruptcy in case of a failed innovation.

Hence, from this perspective one may argue that public funding should be strongly associated with radical innovation projects, rather than incremental innovations. Empirically, some studies have shown that public R&D is more efficient at promoting radical innovations than incremental innovations (Beck et al., 2016). Block and Keller (2015) showed that among prize-winning US innovations in the 1970s, 35% were developed by public entities or had received federal funding. By 2006, the corresponding figure had increased to 75%, suggesting that government initiatives have become increasingly important. This can be compared to general rates of reliance on government funding. The share of US patents that relied directly on publicly funded research rose from about 10% in the 1970s to 30% in the 2010s (Fleming et al., 2019).

A closely related argument is that innovations may be underprovided in particular in early development stages since these are typically characterized by high risk and fundamental uncertainty (Gallagher et al., 2012; Warwick and Nolan, 2014; Meckling et al., 2022). In the bigger picture, government funding has been argued to be essential in providing funding of fundamental technology in high-risk early stages of technological revolutions, such as early computers and ICT technology (Block and Keller, 2015). Some studies argue that public support is crucial throughout the innovation process, but others have suggested that early stage funding may be associated with more positive outcomes. For instance, Howell (2017) found a positive relationship between the performance of US firms and public funding but only during early development stages. If public funding was only obtained during later stages of the innovation process, no similar positive effects on innovation outcomes were found.

Another line of argument is that undertaking risky innovation projects may be especially problematic for small firms. Large incumbents can retain earnings to fund innovation projects, whereas small firms often face a funding gap (Hall and Lerner, 2010). In addition, small firms have since the 1980s been increasingly and more often responsible for radical innovations than large firms (Acs and Audretsch, 1990; Hylmö and Taalbi, 2024). Empirically, some studies have found that the impact of public funding had a greater effect on R&D in large firms (Carmichael, 1981). Overall, public funding tends to have a positive impact on small firms, although there are important nuances. A Swedish study showed that early-stage government subsidies increase the success of new firms, in part by a signaling effect and by increasing the likelihood of receiving further financial support (Söderblom et al., 2015). Others have shown the reverse effect where subsidies on R&D is higher for small firms (e.g., González and Pazó, 2008). Lerner (2000) found an effect of small business innovation programs, but only in regions with significant venture financing, suggesting that public funding acts as a complement to venture capital.

However, the risk of government failures speaks against the view that public funding should aim to support radical or early-stage innovation, or replace private capital. Governments are often argued to be less efficient than private investors at identifying promising projects when knowledge is distributed (Hayek, 1945; Krueger, 1974; Lerner, 2009). Hence, governments should not attempt to pick winners. The other reason offered against public involvement is the creation of incentives for *rent-seeking* behavior (Krueger, 1974). Firms will attempt to receive as much public funding as possible to maximize their short-term profits while delivering only a minimum of required results. For these reasons, this strand of literature has called for a reduction of governmental involvement in technological development (Kealey, 2001; David, 1997).

More recent literature has pushed back some of these critiques. Rodrik (2014) argues that the problem of picking winners is “largely irrelevant” and that efficient industrial policy necessarily involves some failure. Failures are a natural part of discovery processes but investments of public actors tend to be scrutinized more closely than private investments, since failed public investment is associated with a waste of tax money (Meckling et al., 2022). What governments should focus on is *letting losers go* to avoid major losses of tax money. Public funding should only be provided to projects fulfilling clearly outlined, measurable conditions. Projects failing to comply with these should be denied further access to additional public funding. (Hausmann and Rodrik, 2003; Rodrik, 2007; Juhász et al., 2024).

Recent thinking suggests that rather than top-down designs, public innovation policy should facilitate discovery processes and let “winners pick themselves” (Rodrik, 2007), or designing ambitious goals that create new markets and “pick

the willing” (Mazzucato, 2013). The role of public funding is along these lines not to perform private capital functions, but to create new markets and to facilitate underprovided discovery processes.

This brings us to the second important motivation for public innovation funding that relates specifically to clean tech and renewable energy technology. Greenhouse gas emissions have been called the “biggest market failure the world has ever seen” (Stern, 2008, p. 1) and the problem of creating incentives and a market for technologies that replace fossil fuels are more than apparent. The strong path dependency of technological change coupled with the fact that sustainability is a complex “wicked problem” motivates government interventions. Since innovation is strongly path dependent, Aghion et al. (2019) argue that the shift towards renewable energy and clean tech requires direct innovation funding and that governments need to mobilize private market forces towards clean energy. To facilitate a transition towards renewable sources, systemic changes are required that are infeasible to single companies (Acemoglu et al., 2016; Aiginger and Rodrik, 2020; Mazzucato, 2018; Meckling et al., 2022).

Energy technology has characteristics at the intersection of several of the above-mentioned motivations for public innovation funding. Previous research shows that renewable energy technologies in their early stages of development are characterized by high-risk and low short-run rewards, making them particularly unattractive to private investors (Jolink and Niesten, 2021). Private investors opt for investments in low-risk, fossil-fuel technologies, or renewable energy technologies approaching market maturity (Gallagher et al., 2012; Zhang et al., 2021). Hence, public funding may fill this gap by providing support for renewable energy technologies, particularly during early development stages.

In practice, the commitment to renewable energy is not equally shared across countries or over time. At the global level, investment in energy research, development and demonstration has remained skewed toward nuclear and fossil fuels despite rapid increasing investment in clean energy (Zhang et al., 2021; Meckling et al., 2022). In the eight countries that have the largest energy R&D, fossil fuel R&D share remained stable throughout 2000-2018 (Meckling et al., 2022). Zhang et al. (2021) argue that public investment in energy technologies have traditionally been correlated with increased oil prices. Similarly, when oil prices were rising during the 2010s, government investments in energy increased, but have leveled off since, except in a handful of countries. These observations are worrisome. Reactive energy policy implies volatility and unpredictability (Nemet, 2009). In addition, market shaping policies are if anything needed in the absence of market incentives such as high energy prices rather in their presence.

In sum, there are sound reasons for public funding to aim to support radical innovation, small firms and early-stage projects. This is also true of energy

innovations in general, and clean energy in particular. However, the classical critique of public innovation raises concerns that have not yet been resolved. The central conflict of ideas is between scholars that highlight government failures and innovation scholars that emphasize the state's ability to foster transformative technological change. If the latter view holds, public funding should be systematically and consistently associated with types of innovations that markets are unlikely to produce due to uncertainty or long-term horizons. So far, empirical evidence remains limited regarding whether public funding is actually directed toward radical and clean tech innovation.

3 Public innovation funding in Sweden

To situate our analysis in the appropriate context, this section outlines the emergence of public innovation funding in Sweden and its evolution over the research period, focusing in particular on how funding priorities have evolved. Figure 1 illustrates the evolution of innovation related agencies. Abbreviations, responsibilities, and operation of additional organizations, are listed in Supplementary Table 2.

3.1 Evolution of Swedish innovation agencies

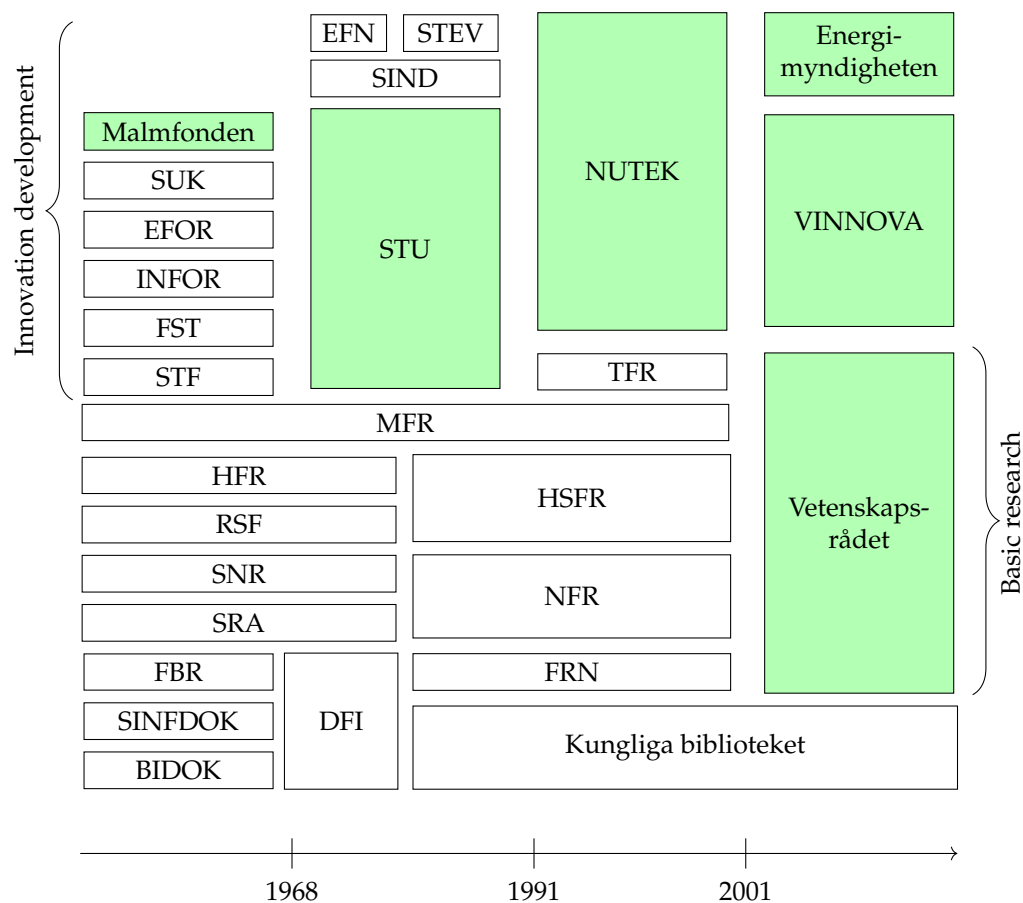
The Swedish government started to fund academic research around the year 1900, establishing research institutes related to its main export sectors¹, which conducted research in mining (Weinberger, 1997, pp. 33-38). However, funding was mostly limited to basic research, providing little support to applied research. During the 1960s, this came under scrutiny during, when the Swedish innovation system was evaluated by the OECD (Arnold and Barker, 2022). In response, the Swedish government established several public agencies that should provide support for applied research.²

In 1968, Sweden went one step further when it established its first official innovation agency STU (*Styrelsen för teknisk utveckling*), merging Malmfonden, EFOR, INFOR, the technical research council (TFR), and the Swedish inventors office (SUK) (Åström et al., 2011; Weinberger, 1997, p. 385-395). It is considered an early example of a second generation innovation agency as its purpose is directly tied to fostering applied research in industrial areas of particular

¹Examples include the agricultural institutes (*lantbruksinstitut*) in Ultuna and Alnarp, the forest institute (*skogsbruksinstitutet*), and the Geological Survey of Sweden (*Sveriges geologiska undersökningar*)

²Agencies founded during this period include Malmfonden, EFOR *Stiftelsen för exploatering av forskningsresultat*, and INFOR *Institutet för nyttiggörande av forskningsresultat* (Sveriges Riksdag, 1961, 1964).

Figure 1: The public funding landscape



Note: Funding years were slightly adjusted. For example, Malmfonden was listed as a separate agency until 1971 and Energimyndigheten was established in 1998 (see table 2). Organizations highlighted in green are included in the Public Funding Database introduced in Section 4.1.2.

interest (Arnold and Barker, 2022; Perez Vico and Hallonsten, 2019), including manufacturing, forestry, mining, medicine, as well as the energy sector.

Nonetheless, STU did not become an effective agency over night. Merging five different agencies into a single one proved difficult as administrative capacities were in oversupply, while others were absent (Weinberger, 1997, pp. 385-395).³ Further, national and international investigations, mostly conducted by the OECD, revealed that STU simply approved projects that they deemed most promising as long as funds were available (SOU, 1977; Weinberger, 1997, p. 454-456, 460-463), neglecting coordination across projects, follow-ups, and provision of long-term finance.

STU was subsequently reformed to improve its efficiency. In line with Sweden's tradition of sectoral research programs dating back to the 1960s, expert committees were transformed into "areas of need" (*behovsområden*) and had merely an advisory function. Project decisions were instead taken by case managers (Åström et al., 2011; Eklund, 2007, p. 92). Moreover, framework programs (*ram-program*) and detailed peer-reviews were introduced in the late 1970s, with the aim to provide long-term funding for projects in target areas, foster long-standing collaboration, ensure high scientific quality and coordination across projects (Arnold and Barker, 2022; Weinberger, 1997, p. 427-432).

In 1991, STU was replaced by the the Agency for Technical and Industrial Development (*Närings- och teknikutvecklingsverket* – NUTEK) (Sveriges Riksdag, 1991). In addition to STU's responsibilities, NUTEK took over responsibilities from EFN (*Energiforskningsnämnd*), STEV (*Statens energiverket*), and SIND (*Statens industriverket*), thus, becoming a combined innovation, energy, business support, and regional development agency. A special aim of NUTEK was the fostering of innovation networks, particularly of connections between SMEs and universities. However, these efforts were hampered by the limited capacity of SMEs for knowledge absorption (Rolfstam and Ågren, 2013; Eklund, 2007, p. 78).

Nonetheless, simply putting more agencies under a single roof did not end debates around an effective restructuring of the Swedish innovation system (Eklund, 2007, pp. 85-136). Many of the reforms of the conservative government were rushed, as they only expected to stay in office for a single term. Critique was particularly voiced by proponents of the innovation systems literature, who criticized the lacking regard for the actual nature of technical change in neoclassical economic thinking (Edquist, 1993).

³Moreover, STU consisted of several expert committees (*facknämnder*) that operated mostly independently as long as they stayed within their given budget. Weinberger (1997, p. 389) describes the situation that emerged around 1970 as an internal "civil war". Attempts to adjust relative budgets across these expert committees were hampered by threats of those, whose relative importance was reduced, to seek independence from STU.

This was realized with the latest major reform of the Swedish public funding system. In 2001, NUTEK was replaced by the Swedish Agency for Innovation Systems (VINNOVA). In difference to NUTEK, VINNOVA is not the main government agency responsible for the development of energy innovation, since a separate Swedish Energy Agency (*Energimyndigheten*) was established in 1998 (Åström et al., 2011). At the same time, Sweden's multiple research councils were merged into the Swedish Research Council (*Vetenskapsrådet* –VR), responsible for promoting basic research (Arnold and Barker, 2022; Eklund, 2007). VR is responsible to finance technical basic research and, thus, has sizable influence on innovation development.

Sweden's EU membership in 1995 limited the scope of industrial policy, while elevating the importance of public innovation funding (Hall, 2019). EU competition prohibits the provision of direct aid from public authorities to companies (see TFEU Article 107 EU (2008)). While this does not prohibit public R&D funding it clearly dictates to which extent it is feasible. Full coverage is only provided for basic research and any kind of R&D conducted by non-economic actors such as universities. For all other types of R&D, coverage is limited, falling with company size and development closer to commercialization. Public R&D support is particularly restricted if directed to large companies. While public funds can cover a maximum of 25% of their experimental development costs, the corresponding shares for medium and small companies amount to 35% and 45%, respectively. Slightly better coverage of R&D expenditure can be obtained when firms engage in collaboration with other companies and institutions, serving as a mechanism to encourage cross-company collaborations (VINNOVA, 2021; Energimyndigheten, 2019).

In a 2024 European comparison, Sweden ranks at first place in terms of total R&D expenditure as a share of GDP (Eurostat, 2026). However, the share of public funding in total expenditure was only 22%, far below the EU average of 30%. This is a rather modern phenomenon, and a characteristic shared with other Nordic countries (Piekut, 2013). Public innovation funding accounted for 40% of all R&D expenditure in Sweden, until the early 1980s (OECD, 2026).⁴ Thereafter the relative share of government spending in total R&D expenditure drops to approximately 25%, where it stabilized around the turn of the millennial. This is in line with an overall reduction of Swedish government expenditure since the 1980s (Lundberg, 1985).

⁴We combine statistics on Gross domestic expenditure on research and experimental development (GERD) with historical R&D expenditure series covering the period 1964-2023.

3.2 Public funding for energy innovation

Sweden is generally perceived as one of the most environmental friendly countries in the developed world, with one of the cleanest energy mixes (Larsson Heidenblad, 2021; Shmelev and Speck, 2018). Nevertheless, this was not the case in the beginning of this paper's observation period. Despite lacking domestic oil resources, oil consumption grew rapidly after World War II due to the widespread use of cars and the expansion of oil-based electricity generation in the 1960s (Kander, 2002, p. 52-55). In 1970, oil accounted for nearly 80% of total energy consumption in Sweden, which made Sweden highly susceptible to the effects of the oil crises during the 1970s and 1980s (Energimyndigheten, 2026). In the aftermath of the oil crises, policy makers pushed towards a reduction of oil consumption to re-establish energy autonomy (Fink, 2026). Due to increasing electrification and expansion of biofuels, the share of oil in total energy use has dropped below 20% in 2020 (Energimyndigheten, 2026).

One thing that made this transition possible is public support for the development of energy technology. Nevertheless, until the late 1990s, responsibilities for energy related research were shared between main innovation agencies and smaller specialized agencies (Sveriges Riksdag, 1982, 1983).⁵ Since 1998, responsibility for all kinds of energy related tasks and research are combined within the Swedish Energy Agency (*Energimyndigheten*) (Sveriges Riksdag, 1997; Energimyndigheten, 2023). The establishment of Energimyndigheten marks a reorientation of public funding for energy innovation towards renewable energy technology (Fink, 2026).⁶

3.3 From industrial policy to public funding

This brief history conveys that public innovation funding has emerged in place of industrial policy and that priorities in the Swedish innovation system has early on been placed on high quality scientific research, energy innovation and SME-university collaborations. Meanwhile, changes in the functioning and targets of funding bodies may have affected the direction and scope of public innovation funding over time.

⁵The Energy Research Board (*Energiforskningsnämnden* – EFN) was established in 1982 with the purpose to support and coordinate long-term research related to the transition of energy systems (Sveriges Riksdag, 1982). Short- and medium-term research was handled by the State energy company (*Statens energiverk* – STEV) (Sveriges Riksdag, 1983). In addition, STEV was tasked with ensuring energy supply and electrical safety.

⁶According to Fink (2026) the agency was the first to receive specific instructions on supporting the development of renewable energy technologies during every single year during the research period and Energimyndigheten's existence (1998-2021).

4 Methods and Data

4.1 Data

4.1.1 SWINNO

The vast majority of micro-based studies on the relationship between public funding and innovation use patents or R&D as proxies for innovation (Cantner and Kösters, 2012; Howell, 2017; Nast et al., 2024; Pless et al., 2020). However, the relationship between patents and commercialized innovations is complicated by the fact that not all innovations are patented, and not all patents come into economic use. Hence, as noted by Pless et al. (2020) other metrics are needed. Some studies have used surveys, such as the community innovation survey, to analyze the nexus of public funding and innovation (Hottenrott and Richstein, 2020; Bruno et al., 2026). Nevertheless, surveys typically do not offer possibilities for long-term analysis. Other studies have analyzed the reliance of public funding among award-winning innovations in the US (Block and Keller, 2009, 2015) and a recent study investigates the role of public funding on innovation output in Finland (van der Have and Deschryvere, 2026). In this work, we source innovation data from the SWINNO database, which captures significant Swedish innovations since 1970 (Taalbi et al., 2024; Sjöo et al., 2014; Kander et al., 2019). For the engineering industry, data is also available from 1908 onwards (Taalbi, 2021, 2026). The current database covers 4,838 significant Swedish innovations commercialized between 1970 and 2021 (Taalbi et al., 2024).

The collection of innovations is based on screening trade journals following the Literature Based Innovation Output (LBIO) approach.⁷ Trade journals were selected on the basis of having an editorial mission to report about technological and other novelty in their respective field. Innovations were included in the database if the trade journal made clear that they are entirely new or significantly improved goods, processes or services that have entered into commercial use (Taalbi, 2021, p. 228). Thus, SWINNO does not capture incremental innovation (Sjöo et al., 2014). The trade journal articles contain information that allow detailed descriptions of each innovation and key information, including innovating firms, the year of commercialization, collaborating firms and agents and product groups.

To a limited extent, information on public funding access is captured in trade journal articles. However, trade journals do not always report such information and are therefore not representative for the actual extent of public innovation funding.⁸ For this reason, the systematic collection of public funding data was

⁷See Kleinknecht and Bain, 1993 for an early treatment of this methodology.

⁸Torregrosa-Hetland et al. (2019) conducted a survey in which 68% of the firms from the

one of the main tasks faced during the research process.

4.1.2 Public Funding Database

To build a robust micro-database on public funding of innovations, public funding data is compiled from several Swedish public funding agencies that operated since the 1960s. We chose the establishment of Sweden’s first central innovation agency STU in 1968 as the start date for the Public Funding Database. An overview over the different data sources that were combined to form the public funding database can be found in Table 1. It was necessary to combine 7 different data sources since the Swedish public funding landscape has undergone frequent restructuring over the study period, discussed in greater detail in Section 3. The final database contains a total of 121,501 public funding projects from both archival and digital sources.

Table 1: Public funding data

	Time	Observations	Source
Malmfonden	1968-1970	106	Riksarkivet - Manually digitized
STU	1968-1978	7,304	Riksarkivet - Manually digitized
STINS	1979-2001	39,907	Digital Source from Riksarkivet
Energimyndigheten	1998-2008	4,648	Digital Source from Organization
VINNOVA	2001-2009	7,246	Digital Source from Organization
VR	2001-2007	10,032	Digital Source from Organization
SWECRIS	2007-2023	52,258	Publicly available database
Total	1968-2023	121,501	

Two digitized data sets, STINS and SWECRIS account for over 75% of observations and cover a similar amount of the study period. STINS (*STödINStrument*) is a data system for handling regional support in Sweden covering the period from 1965 to 2001 (Riksarkivet, 2024). For the period between 1979 until 2001 it also captures public funding projects from the STU, Nutek, and STEV (*Statens Energiverket*). STINS was discontinued when Nutek was dissolved in 2001. SWECRIS was established in 2008 and comprises research projects from Swedish public (e.g. VINNOVA, Energimyndigheten, VR) and private (e.g. Ragnar Söderbergs Stiftelse, Familjen Kamprads Stiftelse) funding organizations (Vetenskapsrådet, 2022a). A detailed overview of these organizations’ responsibilities and operation periods can be found in Supplementary Table 2. SWECRIS contains information on over 52,000 public funding projects that together received

Swedish sample reported that they received some public funding, compared to a share of 15% reported in the database.

more than 183 billion 2020 SEK.⁹ For this study we only consider project funding from VINNOVA, Energimyndigheten and VR. Thus, organizations who are primarily (VINNOVA, Energimyndigheten) or at least as a secondary function (VR) concerned with innovation development.

Relying on STINS and SWECRIS alone was however insufficient since they do not contain information before 1978 nor from 2001-2007. To cover the pre-1978 period, archival data from STU and the Malmfonden from the Riksarkivet has been digitized, adding 7,410 additional observations to the data set. The remaining gap between 2001 and 2007, was filled by contacting the main public funding agencies operating during this period, VINNOVA, Energimyndigheten, and VR, all of which provided digitized datasets.

The final database contains information on project ids, funding organizations, innovating firms, project titles, project type, granted amounts (converted to 2020 SEK), decision-, start-, and end-years. Sector information is available in the sub-datasets from STU, VR, SWECRIS and STINS. However, sector definitions are inconsistent across time and were disregarded in this analysis since innovations are placed at the center of the regression analysis.¹⁰ Similar inconsistencies were encountered in the reportings of innovating firms, whose names were reported in multiple instances with variations in spelling, placement of firm titles, etc.

Only two type of projects are included in the Public Funding Database, project grants (*projektstöd*) and general funding (*ramprogram*). Nonetheless, the latter is only used for constructing the variable past funding access, since it does not explicitly refer to a single project. Projects targeting regional development are excluded.

The Public Funding Database accounts for approximately 50-75% of the total budget of public funding agencies declared in regulation letters to the innovation agencies. This discrepancy can be accounted for by the exclusion of general, non-project specific funding, as well as the exclusion of administrative and other operational costs in the Public Funding Database.

4.2 Operationalization of direct public innovation funding

Previous research has often defined innovations to receive public funding if the innovating firm relied on public funding in any form (Block and Keller, 2009; van der Have and Deschryvere, 2026), or if a public actor was among the developing companies (Torregrosa-Hetland et al., 2019). In contrast to this, the present study focuses exclusively on *direct* financial flows from public funding institutions to innovating firms, with the purpose to develop the new

⁹17.4 billion 2020 euros.

¹⁰Fink and Torregrosa-Hetland (2026) have developed a classification system for extracting sector information for public funding projects from the Public Funding Database.

technology in question. Thus, we do not consider general funding lacking a specific purpose.

We also consider public funding regardless of the stages of the innovation process (Gallagher et al., 2012; Mazzucato and Semieniuk, 2018). This makes it possible to assess where in the innovation process that public funding was awarded.

4.3 Linking process

One of the main challenges in creating our data was the linking of public projects to innovations from the SWINNO database. The aim of the linking process is to identify innovations and public funding projects that, based on the descriptions derived from trade journals and the public funding database, are deemed to refer to the development of the same product or technology.

Identifying the public funding projects that match the description in SWINNO is challenging due to the sheer size of the public funding database containing over 120,000 observations and therefore also potential matches. Moreover, to correctly identify links, details in the descriptions in SWINNO and the public funding database must be considered. This is further complicated by the use of both Swedish and English in both databases, making any automatic procedure less likely to identify matches correctly.

An approach has been developed to identify potential matches for manual inspection, using information included in SWINNO. This process is visualized in Figure 2. First, potential matches are identified. This includes all projects linked to developing firm(s), containing the innovation name, or keywords from the description. In the second step, potential matches are dropped in case that the project start date is more than 10 years before or after commercialization. Thus, for an innovation commercialized in 1980 only projects starting between 1970 and 1990 are considered. Finally, each remaining potential match is manually reviewed. A link is only established if the descriptions in SWINNO and the Public Funding Database refer with a high probability to the same innovation. It should be noted that, matches are non-exclusive, hence, each innovation can be linked to multiple funding projects and each funding project to multiple innovations.

Through this linking process, we create the majority of public funding links, a minority stemming only from trade journal information. As illustrated in Table 2, we create 860 additional public funding links through the inclusion of public funding information from the linking process.

We are aware that the final step in the linking process involves some conscious choices from researches that could potentially bias its results. To address this concern, one of our research assistants without previous access to our results

Figure 2: Linking process

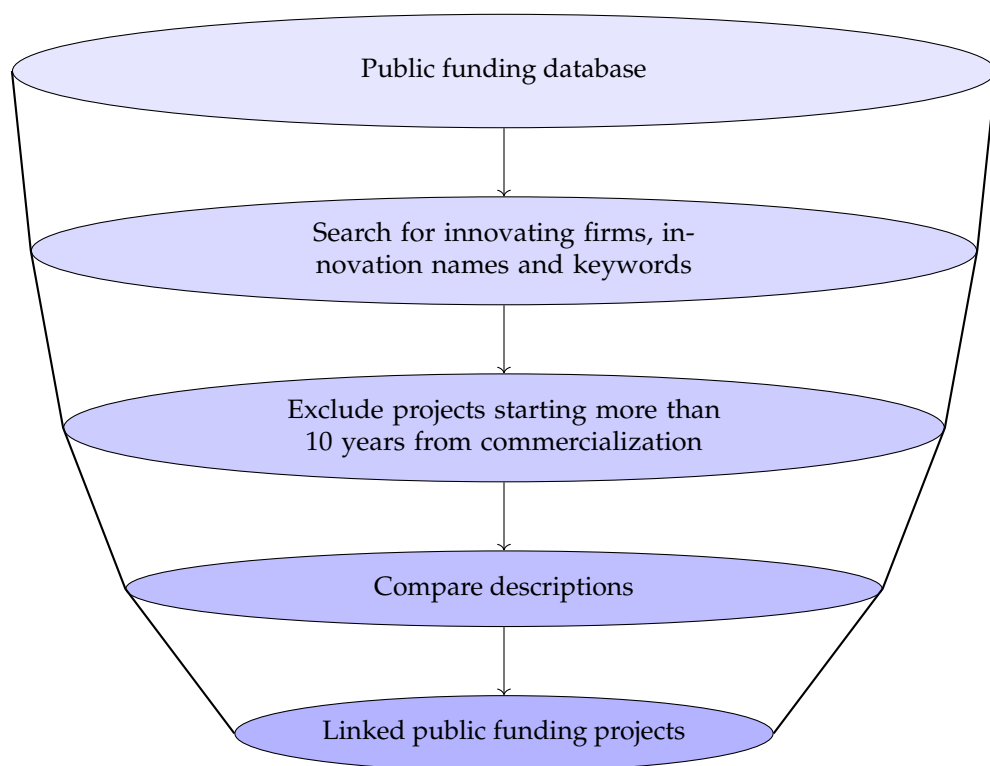


Table 2: Comparison of public funding shares based on SWINNO and the public funding data set

	Public Funding	
	Yes	No
(1) SWINNO	302	4,536
(2) Public funding data	1,033	3,805
(3) Combined	1,162	3,676

Source: SWINNO and Public Funding Database.

from the linking process, has linked a sample of 50 innovations from SWINNO to the Public Funding Database following the methodology outlined above.¹¹ Results of the linking process are compared in Table 3, and separated by innovations declared to have public funding access, (1) our results, that of our (2)

¹¹We are very grateful to Jakob Nyqvist for taking on this additional task.

research assistant, and (3) identical classification by both parties. In 86% of cases we established links between the same innovations in SWINNO and projects in the Public Funding Database. If we only compare overall public funding shares variation between our results is below 5% (22% and 24%, respectively).

Table 3: Comparison of linking results for a sample of 50 innovations.

	Public Funding	
	Yes	No
(1) Our results	11	39
(2) Research assistant	12	38
(3) Identical	8	34

A minor limitation of this analysis is that the public funding database only contains information from 1968 onwards. For this reason, the matching may omit projects with long development time that received public funding before then. Accordingly, public funding propensity among innovations developed during the early 1970 are most likely underestimated. Moreover, we most likely do not fully capture innovation outcomes of public funding projects starting towards the end of the observation period, as we only consider innovations commercialized before 2022. This can be accounted to the delay between initial funding and the creation of an economically viable product (Min et al., 2020). However, since innovations are the central subject of our study, we consider this a minor concern.

We compare trends in public funding access with the only comparable previous study Torregrosa-Hetland et al. (2019), that has estimated the public funding propensity in SWINNO based on a survey among innovating firms operating in the ICT sector. The results are presented in Supplementary Figure 3, revealing that despite their estimates being based on an extrapolation rather than on actual data the findings from Torregrosa-Hetland et al. are highly consistent with ours over most of the observation period. Results in both studies are basically identical between 1980 and 1995 and except for the 1970s, our results are consistently within the lower edge of their confidence interval. This supports the validity of the present estimations as well as of Torregrosa-Hetland et al. (2019).

4.4 Logistic regression model and variable description

To analyze what innovation and firm characteristics correlate with receiving public funding, we estimated two sets of logistic regressions. While some previous research has used public funding as independent variable, we wish to

investigate whether characteristics of innovation and of the innovating firm(s) are correlated with the likelihood of receiving funding (compare e.g., Wang et al., 2024).

$$\begin{aligned} \text{logit}(E[PF_{i,t} \mid X_{i,k,t}]) = & \beta_0 + \beta_1 E_i + \beta_2 C_i + \beta_4 P_i + \beta_5 S_i + \beta_6 lS_i \\ & + \beta_7 T_{k,t} + \beta_8 Publ_k + \beta_9 Small_{k,t} + \beta_{10} Large_{k,t} \\ & + \beta_{11} \left[\sum_{t_z < t}^{t-1} N_{k,t_z} \neq 0 \right] + \beta_{12} \left[\sum_{t_z < t}^{t-1} PF_{k,t_z} \neq 0 \right] \\ & + \delta_t + \varepsilon_i \end{aligned} \quad (1)$$

The first model specification, presented in equation 1, addresses differences in public funding access between energy and non-energy innovations. Access to public funding, $PF_{i,t}$, of innovation i is determined based on a set of binary control variables, $X_{i,k,t}$, including whether innovation i is an energy innovation E_i , collaborative C_i , patented P_i , highly significant S_i , or of low significance lS_i . Furthermore, controls at the level of the innovating firm(s) k indicate the involvement of a top innovator $T_{k,t}$ or a public entity $Publ_k$. The size of the innovating firms is captured by $Small_{k,t}$ and $Large_{k,t}$. We also control for whether any of the developing firms had developed innovations previously, $\left[\sum_{t_z < t}^{t-1} N_{k,t_z} \neq 0 \right]$,¹² or had received public funding previously, $\left[\sum_{t_z < t}^{t-1} PF_{k,t_z} \neq 0 \right]$. Finally, δ_t denotes time fixed effects.

In a second specification, we addressed the direction of public funding for energy innovations, by comparing renewable energy innovations with non-renewable energy innovations. Variables used in this regression are similar to the first equation with the exception for a dummy variable R_i which marks innovations relying on renewable energy sources.

$$\begin{aligned} \text{logit}(E[PF_{i,t} \mid X_{i,k,t}]) = & \beta_0 + \beta_1 E_i + \beta_2 C_i + \beta_4 P_i + \beta_5 S_i + \beta_6 lS_i \\ & + \beta_7 T_{k,t} + \beta_8 Publ_k + \beta_9 Small_{k,t} + \beta_{10} Large_{k,t} \\ & + \beta_{11} \left[\sum_{t_z < t}^{t-1} N_{k,t_z} \neq 0 \right] + \beta_{12} \left[\sum_{t_z < t}^{t-1} PF_{k,t_z} \neq 0 \right] \\ & + \delta_t + \varepsilon_i. \end{aligned} \quad (2)$$

Since the analysis is conducted on the innovation level, firm characteristics are collapsed, such that the dummy variables $Publ_k$, $\left[\sum_{t_z < t}^{t-1} N_{k,t_z} \neq 0 \right]$, and $\left[\sum_{t_z < t}^{t-1} PF_{k,t_z} \neq 0 \right]$, take the value 1 if any of the developing firms is under public ownership, innovated previously, or applied for public funding. In the remainder of this section all the regression variables are presented in greater detail.

¹² $[\cdot]$ denotes an Iverson bracket, which equals 1 if the enclosed condition is true and 0 otherwise.

4.4.1 Innovation-level controls

Public funding

The outcome variable $PF_{i,t}$ takes the value one if the innovation i can be directly linked to a public funding project and zero otherwise (see Section 4.2). Equation 1 estimates the correlation between the public funding propensity of an innovation i , based on a number of control variables X . t refers to i 's commercialization year.

Energy innovation

An innovation is considered as an energy innovation E_i if it falls into one or multiple of the subcategories listed in Table 4. A novel hybrid electric vehicle would simultaneously be classified as an innovation related to electricity, fuel, and fossil fuel. Categorization was done manually based on the description obtained from trade journal articles. Therefore, the sum of energy innovations falling into each single categories does not add up to the total of 682 energy innovations identified in this study.

Table 4: Number and share of energy innovations by subcategory

	Number	Share
Distribution	70	11%
Electricity	238	34%
Efficiency	304	43%
Emissions	57	8%
Fuel	246	35%
Heat	220	32%
Storage	44	6%
Biomass	39	6%
Fossil	126	18%
Geo	4	1%
Hydro	12	2%
Nuclear	17	2%
Solar	42	6%
Waste	8	1%
Wind	14	2%
Total	682	100%

Note: Categories may overlap and the number and share of energy innovations by category do not add up to the total of 682 or 100%.

The source material contains information on the type of energy use available for

all energy innovations, while the energy source is explicitly mentioned only in 252 cases, accounting for 37% of energy innovations. Two fifths of all energy innovations are related to the more efficient use of energy. Innovations related to the use of fuel and electricity account for 35% and 32% of all energy innovations, respectively.

The second model specification only considers energy innovations. Therefore, the aim of the second model specification is to estimate the relative public funding propensity of renewable energy innovations. This paper follows the definition by Panwar et al.: “[r]enewable energy sources are those resources which can be used to produce energy again and again, e.g. solar energy, wind energy, biomass energy, geothermal energy, etc. and are also often called alternative sources of energy. [They] have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases.” (Panwar et al., 2011, p. 1514). In this paper, biomass, geothermal, hydro, solar and wind energy are classified as renewable sources, while fossil, nuclear and waste are classified as non-renewable sources.

Explicit information on the energy source is provided for 252 innovations. In total 101 and 145 innovations are classified as renewable and non-renewable, respectively. Six innovations concern hybrid technologies and thus fall into both categories. Fossil fuel represent half of the energy innovations with explicit information on the utilized source. Solar power is the most popular renewable sources followed by biomass, each accounting for 6% of energy innovations.

Significance

As discussed in section 2, the motivation for public support of radical innovations is that they are associated with more risk and uncertainty, while holding greater promise and societal value. Radical innovation is elusive and has been defined in the literature along different lines (Capponi et al., 2022; Frenken and Punt, 2023). The concept is usually understood to refer to innovations having a high degree of novelty with respect to existing knowledge and practices while having an impact on industry or technological trajectories (Henderson and Clark, 1990; Dosi, 1982).

Here, it makes sense to approach radical innovation as a combination of *novelty* and *impact*, following a rather sizable literature (Dahlin and Behrens, 2005; Kovacs et al., 2019). However, measuring “impact” requires hindsight, which is unavailable to decision makers. This has made researchers distinguish radicalness *ex ante* and *ex post* (Dahlin and Behrens, 2005).

How then approach radical innovation in practice? The SWINNO database captures significant innovations, reported in trade journals because believed to significant to the general public, to stakeholders or specialist readerships. We view radical innovation as the subset of these significant innovations that

combine novelty with impact, whether expected or in hindsight. We therefore first ask whether public funding correlates with innovations that were described in trade journals as having high novelty and significance during the innovation's development. Secondly, we also ask whether public funding is correlated with innovations that in hindsight were seen as impactful and novel as indicated by prestigious prizes, academic literature and Wikipedia. The former could be seen as a proxy of radicalness *ex ante* and the latter *ex post*.

To grade innovations *ex ante*, according to our trade journal sources we combine information on market novelty, firm novelty and the number of trade journal sources.¹³ All these variables are positively correlated with being patented, having higher numbers of patents and patent citations (Taalbi, 2025).

Alone, these three indicators capture different types of information but have limitations. A limitation in particular is that market novelty is not always explicitly reported (Sjöo et al., 2014). We assume that repeatedly reported innovations reflect not only an above average significance but also novelty. This is certainly true for some of Sweden's most radical innovations, for example ASEA's revolutionary IRB 6 robot, covered 5 times, and Skype, covered 4 times in innovation focus articles. Combining these indicators we grade innovations on a continuum of significance as follows.

- *Highly significant innovations* or "radical innovations", are innovations that were reported at least three times in any journal, or were reported twice but were new to the world market or radical from the firm perspective.
- *Significant innovations* are innovations that were reported only once, or were reported twice but were neither new to the world market or radical from the firm perspective.
- *Low significance innovations* are defined as innovations that were reported only once, incremental to the firm, while not reported as new to the world market.

It is important to recall that the innovation data does not capture product improvements or incremental innovations in general. Hence, low significance innovations represent a lower register of significant innovations, reported as

¹³These concepts are loosely inspired by the terms 'new to the firm' and 'new to the market' applied in CIS, but enables a more elaborate grading of innovations. Market novelty is graded from explicit information in trade journal articles into two categories: new to the Swedish market and new to the world market based on explicit information. Firm novelty grades innovation according to their relation to firms' previous activities. Innovations are 'entirely new' if the product entailed the firm venturing into a new field of technology or was described as a breakthrough or significant improvement for the firm. An innovation was deemed an incremental improvement if the innovation meant minor changes to a previously existing innovation (Sjöo et al., 2014).

new to the Swedish market, rather than the entire population of incremental innovations.

Our second indicator of radicalness is innovations identified *ex post* through prizes and academic literature on major Swedish innovations. We present these data and results as part of our robustness analysis (see Section 5.4) where we compare the association between public funding and *ex ante* and *ex post* radical innovation.

Patent applications before commercialization

Securing intellectual property rights may strengthen the innovations' credibility and viability and hence its likelihood of receiving funding. This is captured in the variable P_i which takes the value 1 if a company applied for a patent prior to its commercialization. For 1970-2021 patent information is sourced from Google Patents that aggregates patent records from official patent offices, including the USPTO, EPO, and WIPO (Johansson et al., 2022; Taalbi, 2025). We count an innovation as having patent applications if there was an application connected to the innovation to any patent offices, including EPO, USPTO, the Swedish Patent Office and e.g., the Japanese Patent Office.

The vast majority of innovations were matched manually. For some more complex technologies and large firms with thousands of patents, matches were made through a machine-learning procedure, matching keywords from trade journal articles to full patent documents. After several rounds of training on verified correct links and testing against an out-of-sample baseline, Multi Layered Perceptron (MLP) achieved a F1 score of 79.5%. Potential matches from our machine-learning method were screened in additional rounds of manual matching to ascertain reliability. The results showed a high correlation between the manual assessment and the MLP's confidence in the innovation-patent pairings, which strongly validates the machine-learning assisted model. Detailed information about the matching process is available in previous work (Johansson et al., 2022; Taalbi, 2025).

Collaboration

The binary variable C_i indicates whether an innovation has been developed in collaboration with other actors. Information on collaborative innovations is entirely based on trade journal sources.

Collaboration with national and international partners is crucial for knowledge exchange and idea diffusion among innovative firms (Chaminade et al., 2018; Bommert, 2010) and several studies point to the existence of a positive correlation between collaboration and public funding propensity (Ubfal and Maffioli, 2011; Ebadi and Schiffauerova, 2015). Moreover, Hottenrott and Lopes-Bento (2014) find that public R&D funding is most effectively translated into

innovation outputs by internationally collaborating firms.

4.4.2 Firm-level controls

Public actor

We control for the involvement of a public actor $Publ_k$, which includes publicly owned firms and organizations and research institutes but even universities and research institutes is important. This is motivated by the fact that these organizations account for approximately 60% of all funding projects included in the database and since their R&D expenses can be covered to a higher extent by public funding entities (VINNOVA, 2021; Energimyndigheten, 2021). Information on ownership is contained as a separate variable in SWINNO, and in some sub-datasets of the Public Funding Database. A firm is declared to be under public ownership if either source lists them as publicly owned.

Company size

The variables $Small_{k,t}$ and $Large_{k,t}$ capture firm size at the time of commercialization. Firm size are standard controls (Jové-Llopis and Segarra-Blasco, 2018; Kesidou and Demirel, 2012; Bronzini and Piselli, 2016; Hottenrott and Lopes-Bento, 2014), but are crucial in the Swedish case since firm size determines to what extent public funding bodies are allowed to support R&D costs (VINNOVA, 2021; Energimyndigheten, 2019).

In this paper we distinguish between small, medium, and large firms, as firms with between 0 and 49 employees, between 50 and 199 employees and 200 employees or more, respectively. Data on firm size at commercialization is obtained from SCB (2023) until 2013 and Weidenman (2025) from 2014 onwards. In practice, we only consider the size of the main innovating firm. Thus, collaborators' size is not considered in the regression model.

The categorization of innovations by the size of their innovating firm is summarized in table 5. The majority of innovations have been developed by small companies with less than 50 employees. Large firms with 200 employees or more constitute the second biggest group, accounting for 26.95% of significant innovations in Sweden.

Past innovation and Top innovator

$[\sum_{t_z < t}^{t-1} N_{k,t_z} \neq 0]$ indicates whether at least one of the firms created an innovation before commercialization t .

As a special case of firms who developed innovation in the past, the variable top innovators is included $T_{k,t}$, indicating the participation of a firm in the innovations process which had developed 10 or more innovations before the launch of the innovation in question. Since the distribution of the number of innovations is heavily skewed towards companies developing a single innovation (82% of

Table 5: Size of the innovating firm

Size	Number	Share
Small	2,645	54.67%
Medium	889	18.38%
Large	1,304	26.95%

Source: SWINNO and SCB.

firms in SWINNO), we use a threshold to identify innovations developed by the top 1% innovative firms. To avoid truncating the data in 1970 and losing observations, we used historical data available back to 1908 (Taalbi, 2021). Top innovators include some of the largest corporate groups, such as Ericsson, ABB, Volvo, Saab and Scania.

Past funding

Indirect effects of public funding are captured by $[\sum_{t_z < t}^{t-1} PF_{k,t_z} \neq 0]$, which takes the value one if the developing firms received public funding in the past. We again prefer a binary variable over a count variable since this variable would be unbalanced for innovations developed in the later phase of the observation period.

4.5 Descriptive statistics

Descriptive statistics for all variables included in the regression are presented in Figure 6. A total of 4,838 innovations were developed over the observation period. Among these, 1,162 innovations, corresponding to 24% of the dataset, have been linked to public funding projects, and 682 or 14.1% of total innovations have been identified as energy innovations.

Table 6: Descriptive statistics

Variable	Obs	Mean	Std. Dev.
Public funding	4,838	.240	.428
Energy innovation	4,838	.141	.353
Renewable source	4,838	.022	.147
Collaboration	4,838	.195	.396
Patented	4,838	.120	.325
High significance	4,838	.210	.407
Low significance	4,838	.093	.290
Public actor	4,838	.058	.234
Small firm	4,838	.547	.498
Large firm	4,838	.270	.444
Top innovator	4,838	.184	.388
Past innovation	4,838	.485	.499
Past funding	4,838	.489	.499

Note: Medium significance and medium-sized firm are the default categories for the regressions and thus not shown.

5 Results

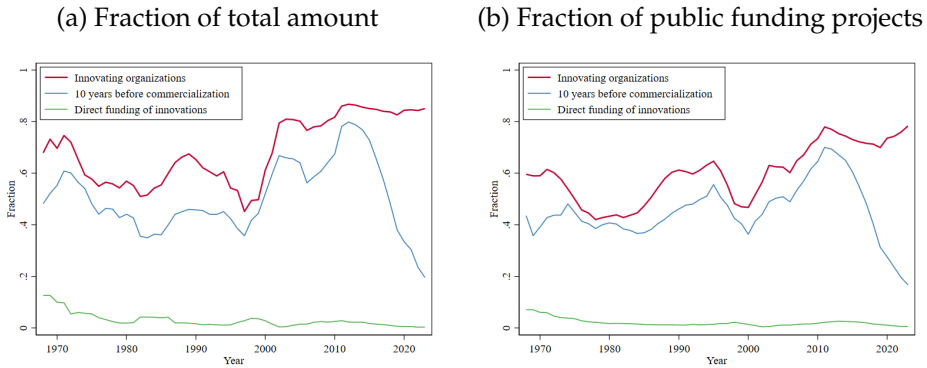
This section presents the evolution of energy innovation and public funding shares over time as well as the results of the logistic regression analysis.

5.1 Public funding of innovating firms

Before delving into specific patterns of funding and innovation, a basic question is to what extent public funding reached innovating organizations. Figure 3 shows that 68.8% of all public funding amounts were awarded to firms that developed significant innovation between 1970 and 2021. Much of previous literature has defined public funding on the firm level, that is, if a firm has relied on public funding prior to the launch of an innovation (Block and Keller, 2009). As depicted in Figure 3, about half (50.5%) of all public funding was awarded to organizations that launched an innovation within 10 years after receiving public funding. An even higher share is observed post 2000. The sharp decrease after 2015 is due to data truncation, since we do not observe innovations launched after 2021. This means that about half of public funding could potentially have had an indirect role in developing innovations, for example by freeing up resources or via spillover effects. However, it is important to note that not all public funding aims to develop new technology. A large portion of

public funding concerns projects without explicit commercial goals, including infrastructure projects, such as the Max IV lab, or basic university research.

Figure 3: Amount of public funding reaching innovating firms, innovating firms within 10 years before launch of an innovation, and direct funding of innovations,1968-2021 (5-year moving average)



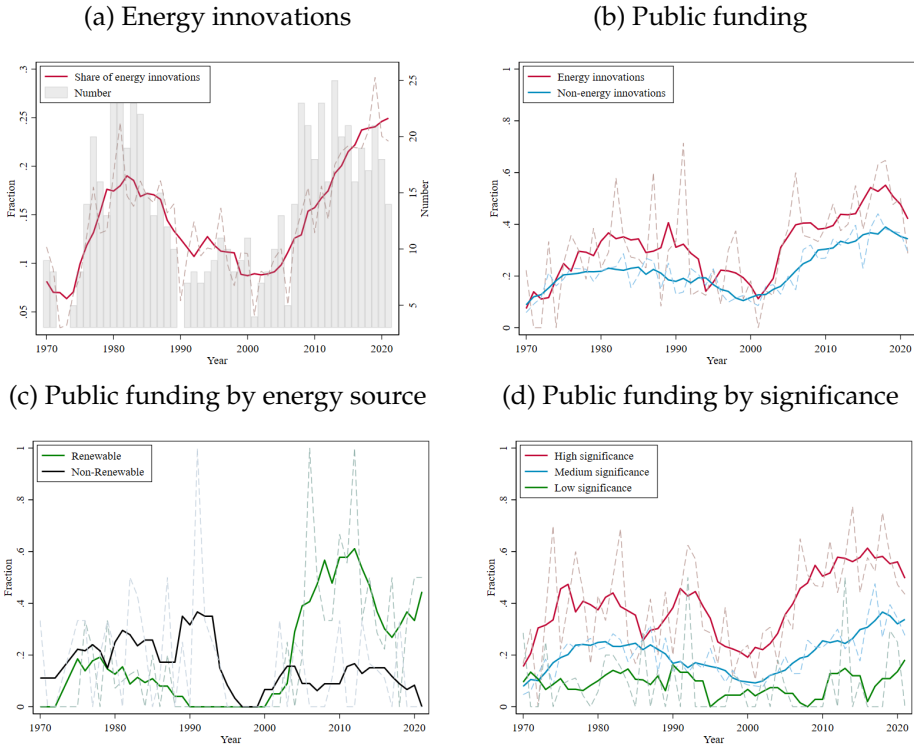
Source: Public Funding Database

Our interest in this study is whether public funding is associated with directionality and radicalness of innovation, thus supporting radical and renewable energy technology. For this purpose, studying whether public funding reached an organization involved in innovation is too broad, capturing funding that is unrelated or only indirectly related to technology development. Instead, our analysis focuses on direct innovation funding, that is, projects explicitly aiming to develop new technology. The results in Figure 3 suggest that a mere 2.95% of all public funding was directly funding the development of innovations. While we are thereby able to assess whether direct public funding of innovations is associated with innovation and firm characteristics, Figure 3 clearly shows that our measure is a conservative estimate of the actual access to public funding.

5.2 Evolution of energy innovation and public funding

As presented in Figure 4a, the number and share of energy innovations has seen two surges, around the mid-1970s and the early 2000s that roughly follow movements in oil prices. Whereas few energy innovations were developed in the first few years of the period, this changed rapidly after the outbreak of the first oil crisis in 1973 when increasing oil prices created financial incentives for investments in novel energy technologies (Grytten, 2020; Zhang et al., 2021). In general, there is a co-movement between the energy innovation share and the oil price (see Supplementary Figure 1). The crude oil price increased threefold

Figure 4: Main variables, 1970-2021 (5-year moving average)



between 1973, peaking at \$116 in 1980. Falling oil prices after 1990 could explain reduced interest both from policy makers and companies for energy technologies. Rising resource demand from Asia has driven up prices once again since the early 2000s (Bértola, 2015). Nonetheless, energy prices alone cannot explain trends in energy innovation funding since neither their share nor public support diminished after the most recent oil price decline in 2014 (compare Zhang et al., 2021).

Additionally, public innovation policy, climate change mitigation efforts, and a rising concern among consumers must be considered (Jové-Llopis and Segarra-Blasco, 2018; Kesidou and Demirel, 2012). The promotion of renewable innovation and energy efficiency is a central part of the Swedish innovation strategy (Regeringskansliet, 2015). Moreover, increasing environmental concerns among the population motivate companies to invest into energy R&D to improve their image among potential consumers (Raska and Shaw, 2012).

For most of the period, energy innovations relied more on public funding than non-energy innovations, as illustrated in Figure 4b. This difference is especially pronounced in the early 1980s and after 2005, when the share of

public funding of energy innovations exceeded that of non-energy innovations by approximately 10 percentage points.

When comparing public funding shares between renewable and non-renewable energy technologies, the direction of public funding shifted around the year 2000. Figure 4c suggests that prior to 2000 non-renewable innovations constituted the bulk of publicly supported energy innovations, while since the early 2000s, public funding has been strongly channeled towards the development of renewable energy innovations. 35% of renewable energy innovations developed after 2000 received public support this applied to a mere 10% of non-renewable innovations. When disaggregating data for individual renewable sources it becomes apparent that public support was primarily granted to biomass, wind and hydro innovations before 2000, while the majority of public funding in recent years is directed towards solar innovations (see Supplementary Figure 2). A salient result of our study is that public funding had a strong gradient with respect to the significance, or radicalness, of innovations. Figure 4d illustrates that public funding is positively correlated with the innovations' degree of significance. Over the period, the share of highly significant innovations receiving public funding was 43% as compared to only 8% of low significance innovations. Over the last decade (2010-2021), this share was particularly high with 55%.

Figure 5 shows that our results also hold for *ex post* most radical breakthroughs in Swedish history, according to the prestigious Polhem prize, curated lists in academic literature (Wallmark and McQueen, 1991; Sedig and Olson, 2002; Krutmeijer, 2013; Berggren and Krutmeijer, 2023), and innovations discussed as major breakthroughs in Wikipedia entries. Regardless of definitions, highly significant innovations had very similar reliance on public funding. This is discussed in greater detail in Section 5.4.

A key finding is also that the majority of funding was awarded before the innovations' first commercial product. According to Figure 6, 77% of innovations in general and 69% of the most significant innovations received public support prior to the first product launch, while the corresponding shares for energy and non-energy innovations amount to 78% and 73%, respectively. On average, it takes 4 to 5 years from the start of development to commercialization (Taalbi, 2017). Our results highlight that funding in the earliest stages is relatively rare, with less than a third of innovations having received funding four years before commercialization and the bulk of funding being awarded within 3 years before product launch.

Figure 5: Fraction of publicly funded innovations (5-year centered moving averages) among *ex ante* highly significant innovations based on trade journal sources and innovations cited *ex post* as radical innovations according to the Polhem prize, academic literature and Wikipedia.

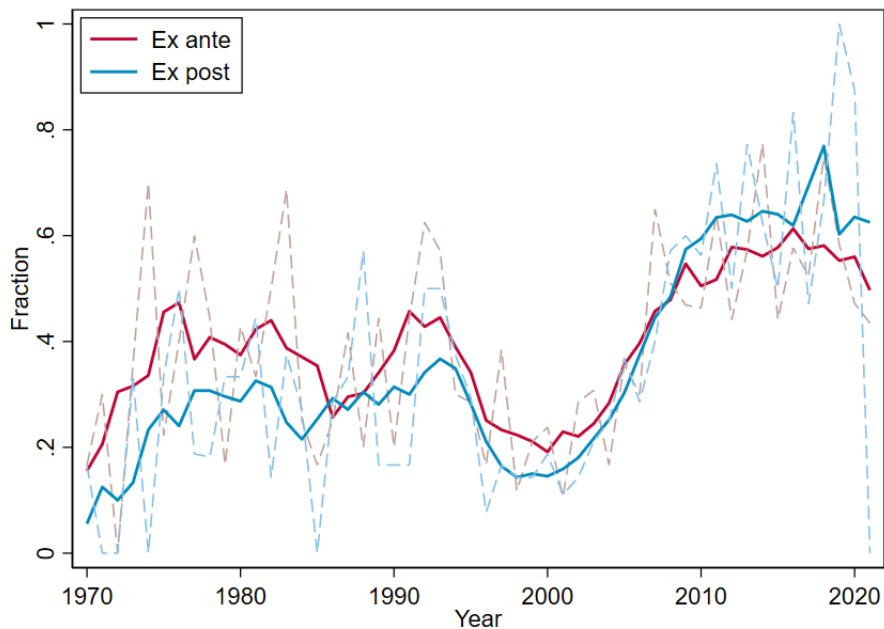
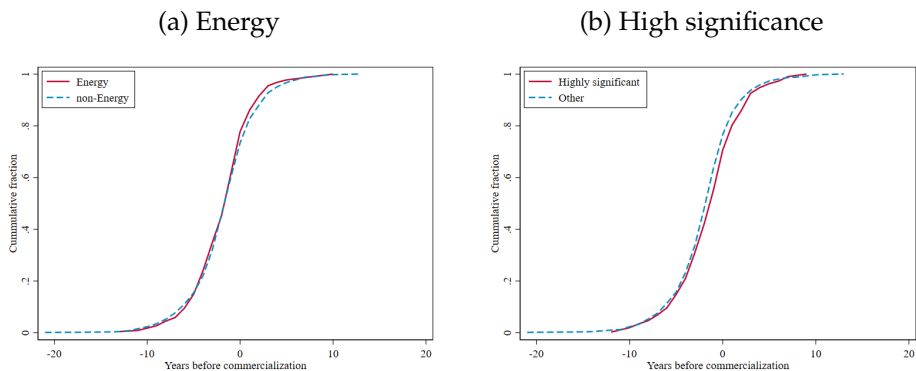


Figure 6: Timing of public funding with respect to year of commercialization, 1970-2021



5.3 Regression analysis of public funding and innovation characteristics

To further understand the relationship between public funding and innovation characteristics, we run logistic regressions. The results in Table 7 are presented as odds ratios and separately for all innovations and the energy sector, as well as for the pre- and post-2000 period. The year 2000 is selected as a threshold for the periodization of this study since it marks both a transition between major public funding organizations and a shift in directionality towards renewable energy technologies (see sections 4.1 and 5.2). Results are discussed separately for the estimations considering all innovations (1)-(3), and for energy innovations only (4)-(6).

5.3.1 All innovations

Energy innovations are 1.6 times as likely to receive public funding compared to non-energy innovations. Moreover, our regressions support the existence of a gradient with respect to the significance of innovations. According to the regression results, highly significant innovations are 2.64 times more likely to receive public funding. The opposite holds true for innovations with low significance, which are 52% less likely to attract public support. We also observe that this gradient has become somewhat stronger over time. These econometric results are robust for changing our definition to *ex post* significance based on externally validated sources, as discussed below in section 5.4.

Regarding firm size, small firms are as expected most likely to attract public support compared to medium and large firms. The effect is stable over time varying only between 2.28 and 2.16 between the pre- and post-2000 period. Also, publicly owned firms are twice as likely to receive public funding throughout the observation period.

The results also reveal other correlations. Innovations that filed for patent before commercialization were 1.9 times as likely to have received public funding, in line with the notion that intellectual property rights may strengthen the innovation's credibility. We did not find a significant effect regarding the likelihood of collaborative innovations to attract public funding. This defies expectations since public funding bodies provided special incentives for engaging in collaborative innovation in recent years (Energimyndigheten, 2019; VINNOVA, 2021).

Innovations developed by firms that had previously participated in the development of another innovation were 34% less likely to receive public funding as first-time innovators. This result is emphasized among "top innovators", firms developing at least 10 innovations prior to the innovation in question, who were

Table 7: Logistic regression results

	All innovations			Energy innovations		
	1970-2021	1970-1999	2000-2021	1970-2021	1970-1999	2000-2021
Energy	1.597*** (0.000)	1.582** (0.002)	1.623*** (0.001)			
Renewable				1.658 (0.063)	0.740 (0.555)	2.526** (0.006)
Collaboration	0.959 (0.706)	0.985 (0.919)	0.925 (0.633)	1.087 (0.779)	1.366 (0.495)	0.796 (0.579)
Patented	1.923*** (0.000)	1.594** (0.006)	2.341*** (0.000)	1.873 (0.078)	1.452 (0.473)	2.324 (0.109)
High significance	2.639*** (0.000)	2.390*** (0.000)	2.776*** (0.000)	4.613*** (0.000)	8.131*** (0.000)	4.460*** (0.000)
Low significance	0.475*** (0.000)	0.499** (0.003)	0.447** (0.007)	0.761 (0.576)	0.132 (0.111)	1.645 (0.403)
Public	2.033*** (0.000)	2.030** (0.003)	2.089** (0.002)	1.781 (0.163)	4.568* (0.019)	0.827 (0.743)
Small firm	2.238*** (0.000)	2.277*** (0.000)	2.162*** (0.000)	2.234** (0.006)	2.417 (0.057)	2.954** (0.010)
Large firm	0.718* (0.015)	0.730 (0.070)	0.625* (0.046)	0.647 (0.186)	0.887 (0.805)	0.525 (0.200)
Top innovator	0.618*** (0.000)	0.586*** (0.001)	0.664* (0.029)	0.405** (0.003)	0.138*** (0.000)	1.202 (0.678)
Past innovation	0.664*** (0.000)	0.660** (0.003)	0.675** (0.007)	0.740 (0.273)	0.747 (0.519)	0.640 (0.218)
Past funding	4.681*** (0.000)	5.884*** (0.000)	3.766*** (0.000)	5.179*** (0.000)	7.822*** (0.000)	4.623*** (0.000)
Constant	0.055*** (0.000)	0.054*** (0.000)	0.022*** (0.000)	0.264 (0.129)	0.316 (0.221)	0.022*** (0.000)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,838	2,679	2,159	682	342	340
R ²	0.187	0.162	0.201	0.249	0.300	0.239

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Dependent variable is whether an innovation received public funding. Coefficients are presented as odds ratios. Values above (below) 1 imply a positive (negative) correlation with public funding.

found to have a 38% lower likelihood to innovate with help of public resources. Finally, past funding raises the likelihood of receiving public funding under all model specifications. During the pre-2000 period it amounts to a staggering 5.89. This finding points to the possible existence of a "seal of approval" among public funding agencies in Sweden (Wang et al., 2004), or a "signalling effect" where public funding increases the probability of further funding (Söderblom et al., 2015). Once a company has been deemed promising enough to receive public support, their future innovations are deemed more promising and therefore

more likely to attract public interest. Although this does not necessarily imply rent-seeking, this result may be read as worrisome since it holds the *potential* to incentivize rent-seeking behavior.

5.3.2 Energy innovations

Regression results for energy innovation largely resemble those for all innovations. However, more of the estimates lack statistical significance, in part due to the fact that energy innovations only account for 14% of the entire sample.

The main purpose of including these regressions separately is to determine whether public funding is correlated with the directionality of energy innovations. In accordance with the trends discussed in the previous section, the estimation results indicate a trend shift in the direction of public funding around the year 2000 (compare Figure 4c). Based on our results renewable energy innovations developed after 2000 were found to be 2.5 times more likely to receive public funding.

Moreover, highly significant energy innovation are particularly likely to receive public support, the magnitude of the coefficient being 4.6, nearly twice as large compared to the complete sample. What should be noted here is that in contrast to innovations in general, high significance is of particular importance before 2000, where the effect amounts to 8.13. Interestingly, innovations with low significance are not significantly less likely to receive public funding when only energy innovations are considered. This most likely can be accounted to the fact that only 48 energy innovations are reported to be of low significance. Otherwise it could indicate that public funding bodies are willing to support even the development of less promising energy innovations.

Another example of an effect that is amplified when only energy innovations are considered is the impact of past public funding. This effect is particularly strong before 2000, where the previous approval of at least one of the collaborators increases chances to receive public funding by a factor of 7.82.

The involvement of top innovators in the innovation process reduces the likelihood that an energy innovations receives public funding by 60%. Notably, this effect disappears after 2000, and firms developing innovations in general prior to the innovation in question are not generally less likely to receive public funding.

Publicly owned firms are found to only in the pre-2000 period be more likely to attract public support. Regarding firm size small firms were also when merely energy innovations are considered more likely to receive public funding. This effect is emphasized after 2000, where it rises to 2.95.

5.4 Additional analyses

Here we carry out multiple robustness tests for our main regression results in Table 7. In particular, we delve deeper into the correlation between public funding and significance of innovations.

To address potential concerns about the validity of our trade journal-based indicator, of significance we carry out additional regressions based on measures of *ex post* radical innovations, and alternative measures of significance. The theoretical motivation for the public funding of radical innovations is that they are more likely to be underprovided. In the perspective of Rodrik (2014), public funding should support discovery processes and (radical) innovations even if they fail or do not become successful. Our main measure of significance does not reflect *ex post* significance. However, if publicly funding does not also correlate with *ex post* significance, one could indeed wonder why governments should try to pick winners.

A methodological concern about our main variable is also that trade journals in theory may write articles explicitly to report about public funding, which could inflate the correlation between high significance and public funding. For this reason, we run regressions where we excluded all innovations that were mentioned to have public funding in trade journals as a robustness check.

5.4.1 Regression with *ex post* significance

For our first alternative regression, we construct a classification of *ex post* radical innovations. To this end, we assembled information about highly radical innovations from three sources. We include recipients of the prestigious Polhem Prize (N=31) awarded annually by the Swedish Association of Graduate Engineers for ingenious solutions of technological problems. We also include major innovations from curated lists in academic independent literature (N=55) (Wallmark and McQueen, 1991; Sedig and Olson, 2002; Krutmeijer, 2013; Berggren and Krutmeijer, 2023). As the main source we also use innovations that were mentioned as notable advances on Wikipedia (N=591) (Wikipedia, 2024).¹⁴

¹⁴Wikipedia is an online encyclopedia whose content is created, edited and maintained by volunteers. The three core principles behind Wikipedia are verifiability, neutrality and "no original research". In addition, adding pages for companies and corporations is subject to special verifiability rules: no company is considered to have inherent or inherited notability (Wikipedia, 2024). Even though persons closely connected to an idea, innovation, or company could potentially suggest and edit pages, regular edits and monitoring from Wikipedia's community should in principle work as to remove or edit content that is not neutral or cannot be verified to be notable. Through our searches, we have not detected any references to the SWINNO database that may in theory have influenced the posting of articles on innovations on Wikipedia. None of the authors of this study has edited content about Swedish innovations on Wikipedia. The collection of innovations from Wikipedia was carried out in March and April 2024.

Regressions with significance based on academic literature, prizes and Wikipedia are presented in Table 8. The results support our main conclusions, with similar or higher correlations between high *ex post* significance and reliance on public funding.

Figure 7: Ex ante – Ex post taxonomy

		Ex post	
		No	Yes
Ex ante	No	Non-radical	Unexpected
	Yes	Potential	Anticipated

It is possible, however, to probe deeper into the role of public funding by comparing *ex ante* and *ex post* radical innovations. We use a simple taxonomy, as presented in table 7. Innovations that were not described as radical *ex ante* but were considered radical *ex post* can be considered “unexpected” radical innovations. Innovations that were described as radical both *ex ante* and *ex post* can be viewed as “anticipated” radical innovations. If public funding picks winners it should be associated with one or both of these types of radical innovations. Conversely, innovations that were not among our *ex post* radical innovations can be divided in those that were not described as such *ex ante* and those that were. The former group may be called “non-radical” innovations. It would be perhaps tempting to describe the latter group as “overestimated”. However, since our *ex post* radical innovations are based on rather selective criteria, it is more accurate to refer to these as innovations with a radical “potential”.¹⁵ Table 9 shows once more a clear gradient. 18% of innovations that were non-radical relied on public funding. This is compared to 47.4% that were anticipated radical innovations. Among innovations with a radical potential but that did not become one of the most radical innovations 41.6% relied on public funding. 25.4% of “unexpected” radical innovations relied on public funding over the full period. This is close to the overall average, and only 7 percentage points higher than non-radical innovations. However, in the post-2000 period 37.5% of “unexpected” radical innovations relied on public funding as compared to 19.2% among non-radical innovations. It seems thus that public funding had an association with innovations becoming radical *ex post*, also compared to *ex ante*

¹⁵Note that not being included among the *ex post* radical innovations does not mean that these innovations failed.

Table 8: Logistic regressions with *ex post* significance. Dependent variable is whether an innovation received public funding.

	All innovations			Energy innovations		
	1970-2021	1970-1999	2000-2021	1970-2021	1970-1999	2000-2021
Energy	1.614*** (0.000)	1.589** (0.001)	1.620*** (0.001)			
Renewable				1.324 (0.315)	0.894 (0.824)	1.710 (0.119)
Collaboration	1.027 (0.811)	1.050 (0.743)	0.977 (0.886)	1.137 (0.668)	1.773 (0.179)	0.700 (0.405)
Patented	2.089*** (0.000)	1.711** (0.001)	2.636*** (0.000)	1.876 (0.073)	1.381 (0.520)	2.607 (0.062)
High significance	2.149*** (0.000)	1.482* (0.018)	2.815*** (0.000)	7.246*** (0.000)	6.955*** (0.000)	7.938*** (0.000)
Low significance	0.387*** (0.000)	0.434*** (0.000)	0.344*** (0.000)	0.622 (0.318)	0.158 (0.107)	1.293 (0.668)
Top innovator	0.621*** (0.000)	0.595*** (0.001)	0.675* (0.035)	0.336*** (0.000)	0.149*** (0.000)	0.817 (0.656)
Public	2.111*** (0.000)	1.996** (0.003)	2.284*** (0.001)	2.354* (0.041)	3.066 (0.070)	1.735 (0.353)
Small	2.356*** (0.000)	2.347*** (0.000)	2.306*** (0.000)	3.082*** (0.000)	2.223 (0.080)	5.251*** (0.000)
Large	0.694** (0.007)	0.727 (0.065)	0.572* (0.018)	0.771 (0.442)	0.798 (0.644)	0.741 (0.565)
Past innovation	0.670*** (0.000)	0.673** (0.005)	0.670** (0.006)	0.815 (0.455)	0.781 (0.576)	0.774 (0.484)
Past funding	4.485*** (0.000)	5.595*** (0.000)	3.728*** (0.000)	4.470*** (0.000)	6.478*** (0.000)	3.813*** (0.000)
Constant	0.054*** (0.000)	0.056*** (0.000)	0.022*** (0.000)	0.085*** (0.000)	0.099** (0.002)	0.006*** (0.000)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,838	2,679	2,159	702	358	344
R^2	0.175	0.121	0.151	0.256	0.280	0.251

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 9: Public funding by types of *ex ante* and *ex post* radicalness.

	1970-1999	1970-1999	1970-1999
Non-radical	0.177	0.192	0.183
Potential	0.340	0.456	0.416
Unexpected	0.191	0.375	0.254
Anticipated	0.364	0.518	0.474
Total	0.199	0.291	0.240

Table 10: Percentage distribution of types of radical innovations by public funding reliance and period.

	1970-1999	2000-2021	1970-2021
Without PF			
Non-radical	82.4	72.4	78.2
Potential	7.5	16.4	11.2
Unexpected	7.5	4.2	6.1
Anticipated	2.6	7.0	4.4
Total	100.0	100.0	100.0
With PF			
Non-radical	71.3	42.0	55.5
Potential	15.5	33.4	25.2
Unexpected	7.1	6.2	6.6
Anticipated	6.0	18.3	12.7
Total	100.0	100.0	100.0

expectations.

To formally test whether public funding is associated with a higher *ex post* significance of innovations as compared to *ex ante* significance, we run a regression with *ex post* radical innovations as dependent variables, including both public funding and *ex ante* radicalness as independent variables, among with other control variables. The results corroborate the above interpretation. Innovations were 1.677 times more probable to become *ex post* radical with public funding. However, this effect mostly emerged after 2000, whereas the effect during 1970-1999 was positive but not statistically significant. In other words, before 2000 publicly funded innovations were only somewhat more likely to become radical

Table 11: Logistic regressions. Dependent variable is whether an innovation became a radical innovation, *ex post*.

	All innovations		
	1970-2021	1970-1999	2000-2021
Public funding	1.677*** (0.000)	1.303 (0.123)	2.007*** (0.000)
Energy	0.895 (0.412)	0.565* (0.013)	1.210 (0.273)
Collaboration	0.848 (0.224)	0.883 (0.500)	0.845 (0.402)
Patented	1.891*** (0.000)	2.602*** (0.000)	1.316 (0.148)
High significance	4.891*** (0.000)	3.739*** (0.000)	5.940*** (0.000)
Low significance	1.087 (0.648)	1.200 (0.401)	0.750 (0.419)
Top innovator	1.527** (0.002)	1.773** (0.001)	1.189 (0.424)
Public	0.640* (0.049)	0.635 (0.181)	0.650 (0.165)
Small firm	0.942 (0.671)	0.800 (0.274)	1.053 (0.800)
Large firm	1.654** (0.001)	1.409 (0.087)	1.905* (0.012)
Past innovation	1.199 (0.153)	1.167 (0.413)	1.258 (0.192)
Past funding	1.263 (0.055)	1.543* (0.017)	1.072 (0.679)
Constant	0.034*** (0.000)	0.037*** (0.000)	0.058*** (0.000)
Time FE	Yes	Yes	Yes
Observations	4838	2679	2159
Pseudo R ²	0.142	0.126	0.168

ex post as deemed *ex ante*.

A complementary lens is to what extent innovations with and without funding end up being in these taxonomy groups, as shown in Table 10. *Ex post* radical innovations are rare, making up 10.5% of innovations without public funding and 19.3% of innovations with public funding. Innovations without public funding have been overall consistently more likely to be non-radical. Innovations with radical potential, and innovations that are unexpected and anticipated radical were more common among those that received public funding. The exception is the period 1970-1999 where unexpected radical innovations were about 7% among both innovations with and without public funding.

5.4.2 Considering only information from the public funding database

Another potential worry about the construction of significant innovations is that innovations receiving funding could spur further mentions in trade journals, which may drive the correlation. To control for the possibility that the high effect of significance is partially or wholly driven by a reverse effect, we run separate regressions where we exclude all innovations that were reported to have received public funding in at least one trade journal article. The results are presented in Supplementary Table 1. Again, our main results are corroborated.

6 Discussion

The data presented in this study, linking public funding data to innovation outputs, has allowed a systematic study of long-term trends in innovations and the direction of public innovation funding in Sweden for 1970-2021. Our results reveal that highly significant innovations are consistently most likely to receive public support, being 2.64 times more likely than others to attract public funding. The tendency to fund innovations with high rather than low significance hold up also for *ex post* radical innovations as defined in other sources (see Figure 5). A remarkably high share of the most radical innovations relied on public funding in the last decade, reaching 55% on average in the period 2010-2021. These results support the notion that, contrary to received wisdom, public funding shapes markets, aptly funding more radical projects. Moreover, the energy sector is indeed targeted by public actors, since energy innovations are 1.6 times more likely to receive public support. However, it should be noted that public support and general interest in energy innovations varied over time and was correlated with economic and financial incentives. This changed only in the 2010s when public support for energy innovations remained high despite falling energy prices. It might reflect an increasing

commitment to climate change mitigation efforts among Swedish policy makers and the introduction of Swedish environmental targets that are in line with the Paris agreement and the Mission Innovation incentive (Mazzucato et al., 2015; Mazzucato and Semieniuk, 2018; Mazzucato, 2022; Miljödepartementet, 2019; Regeringskansliet, 2015).

Another important trend is the direction of public funds towards renewable energy technologies since 2000. In the post-2000 period renewable energy innovations were 2.5 times as likely to receive public support, in line with previous studies (Jugend et al., 2020). Hence, our results suggest that public funding agencies may have played a crucial role in climate change mitigation efforts by supporting the development of renewable energy technologies and providing the generally needed support for radical innovation activity in the energy sector.

As in other countries, public funding for energy innovation has been closely coupled to oil prices until around 2010 (Zhang et al., 2021). While this can be accounted to economic motives, we were surprised by this result, since the Swedish government has not prioritized the investment in renewable energy technologies despite its commitment to climate and environmental protection since the late 1960s (Larsson Heidenblad, 2021). One possible explanation for the limited interest in renewable technologies during earlier years is the insecurity around the development of novel energy innovations (Gallagher et al., 2012; Mazzucato et al., 2015; Wang et al., 2024). Especially due to the extended development time, funding bodies might opt for mature conventional energy technologies which generate marketable outcomes within a few years. This would indicate that public agencies before 2000 displayed high levels of risk adversity in their selection of innovation projects, a characteristic that is typically associated with the private sector (Fouquet and Pearson, 2012). Even if we observe a break in 2010, the historical tendency of public funding to follow energy prices as documented by Zhang et al. (2021) illustrates that public policies are not necessarily consistent.

The present results also point to challenges. Slightly below 80% of innovations, received public funding before commercialization (see Figure 6). However, most innovations received public funding only a few years before commercialization. If paired with observations from other studies that public funding has greater additionality in early stages (Howell, 2017), this could be interpreted as problematic and should be further addressed in future studies (see also Mignacca et al., 2025). A limitation of this study, however, is that we cannot directly gauge publicly funded research spin-offs. We cannot therefore drawing strong conclusions in this regard.

Our results also reveal a risk for rent-seeking behavior. Past public funding was a significant predictor of receiving new funding, raising the access to public

funding by a factor of 4.5 even when controlling for the effect of previous innovation. These results are not direct evidence for rent seeking, but recurrent funding may risk promoting such behavior. This may be a risk especially in the energy sector where innovation has longer time frames. Alternatively, innovation agencies might perceive previous investments into a specific project as sunk costs. Thus, they might be tempted to continue funding a project until it produces a measurable outcome to avoid facing critique for a perceived waste of resources (Garland, 1990; Perignat and Fleming, 2022).

The present study has investigated whether public funding in Sweden is consistently supporting innovations that are radical and represent new directions, in line with the new frame of innovation policy (Schot and Steinmueller, 2018). We have, however, not addressed the question of additionality, that is, whether public funding actually adds something that would not exist in its absence (Falk, 2007). The here-presented data offers possibilities for future research. Similar recent work on innovation output (van der Have and Deschryvere, 2026) and work using this dataset and approved and denied public funding projects (Fink and Torregrosa-Hetland, 2026) offers evidence in support of the existence of substantive output additionality. Possible applications also include the analysis of innovation networks and synergies, and whether public funding is crowding out private R&D. Studies conducted in other countries could indicate whether the results of this study are valid in other settings.

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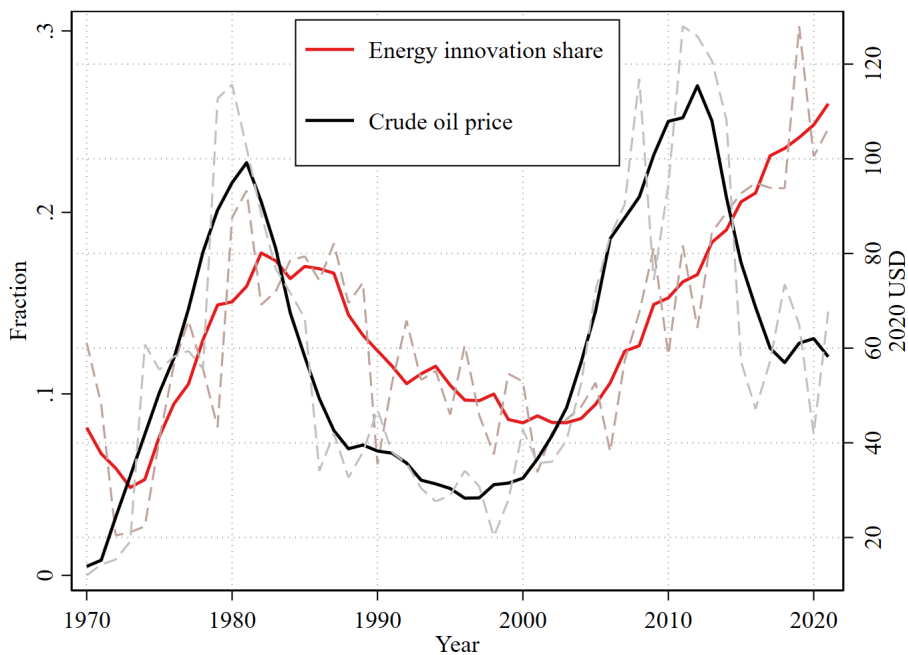
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Additional figures and tables

Supplementary Figure 1: Share of energy innovations vs. Crude oil price, 1970-2021



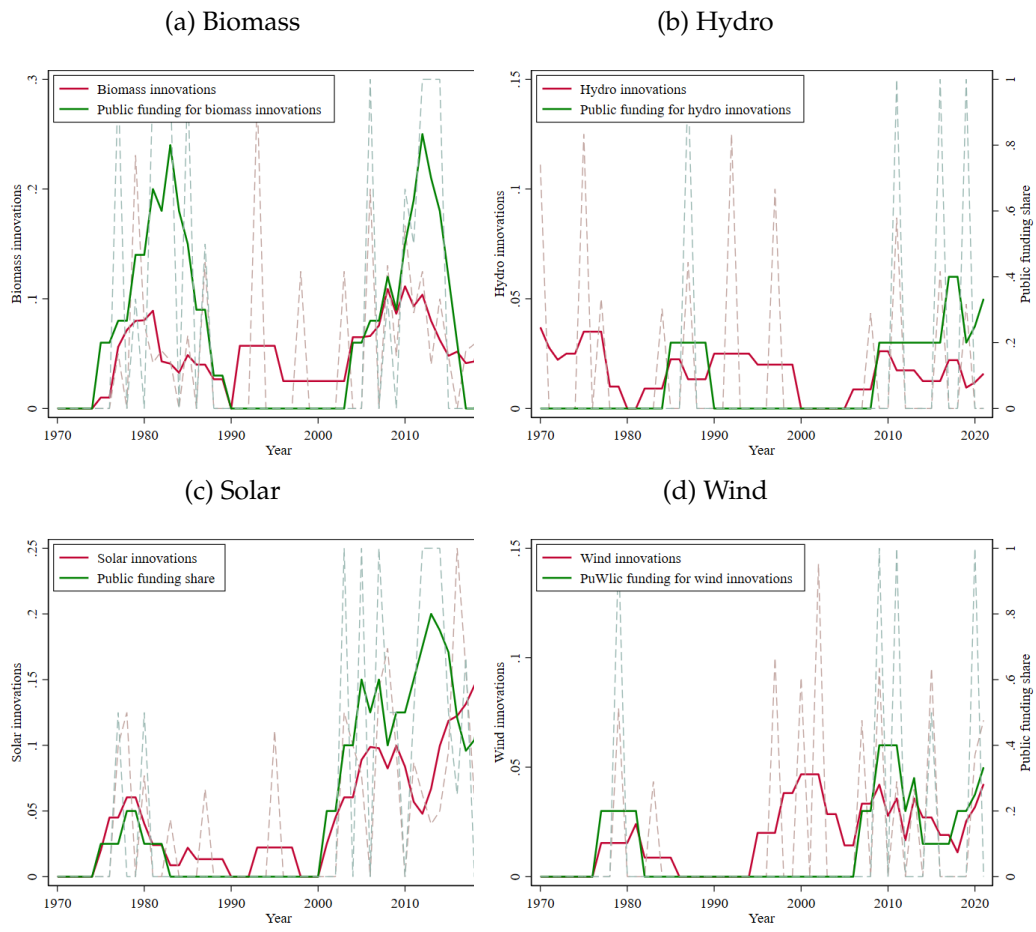
Supplementary Table 1: Logistic regressions based only on public funding database. Dependent variable is whether an innovation received public funding.

	All innovations			Energy innovations		
	1970-2021	1970-1999	2000-2021	1970-2021	1970-1999	2000-2021
Energy	1.582*** (0.000)	1.667** (0.002)	1.534** (0.006)			
Renewable				2.210** (0.009)	1.016 (0.978)	3.415** (0.001)
Collaboration	0.840 (0.161)	0.827 (0.273)	0.844 (0.342)	1.054 (0.868)	1.109 (0.836)	0.823 (0.655)
Patented	1.966*** (0.000)	1.545* (0.022)	2.476*** (0.000)	2.029 (0.064)	1.474 (0.478)	2.521 (0.107)
High significance	2.592*** (0.000)	2.415*** (0.000)	2.656*** (0.000)	4.670*** (0.000)	12.676*** (0.000)	3.781*** (0.000)
Low significance	0.557** (0.003)	0.634 (0.061)	0.468* (0.018)	0.899 (0.837)	0.190 (0.195)	1.992 (0.285)
Top innovator	0.568*** (0.000)	0.545*** (0.001)	0.593* (0.011)	0.439* (0.013)	0.144*** (0.000)	1.154 (0.769)
Public	1.744** (0.004)	1.814* (0.029)	1.732* (0.041)	1.569 (0.325)	5.983* (0.013)	0.654 (0.509)
Small	2.082*** (0.000)	2.026*** (0.000)	2.107*** (0.000)	2.706** (0.003)	2.966* (0.047)	4.279** (0.003)
Large	0.721* (0.029)	0.712 (0.075)	0.632 (0.076)	0.870 (0.708)	1.241 (0.699)	0.781 (0.664)
Past innovation	0.744** (0.007)	0.731* (0.045)	0.767 (0.092)	0.769 (0.390)	0.904 (0.837)	0.613 (0.238)
Past funding	5.264*** (0.000)	6.952*** (0.000)	4.141*** (0.000)	6.210*** (0.000)	8.378*** (0.000)	6.488*** (0.000)
Constant	0.055*** (0.000)	0.055*** (0.000)	0.016*** (0.000)	0.064*** (0.000)	0.052*** (0.001)	0.004*** (0.000)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,536	2,538	1,998	623	319	304
R^2	0.181	0.156	0.195	0.251	0.304	0.255

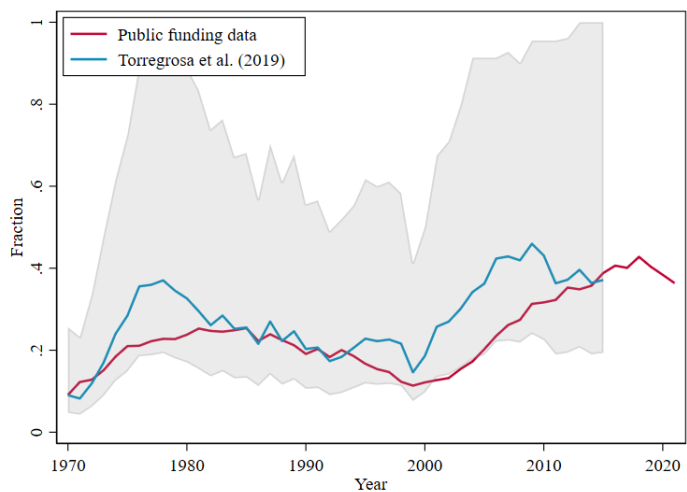
Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Supplementary Figure 2: Share in total innovations and public funding propensity for energy innovations, 1970-2021



Supplementary Figure 3: Comparison of public funding share to previous estimations by Torregrosa-Hetland et al. (2019), 1970-2013(2021)



Supplementary Table 2: Overview of Swedish public funding bodies

Swedish name	Acronym	Start	End	Information	Source
Main innovation agencies					
Styrelsen för Teknisk Utveckling	STU	1968	1991	Promotion of collaboration between academia and industries; focus on "economic areas of special interest", new focus on applied research	Perez Vico and Hallonsten (2019); Åström et al. (2011)
Närings- och teknikutvecklingsverket	NUTEK	1991	2000	Fusion of STU, Industriverket, and Statensenergiverket; contribute to long-term development of the industrial and energy sector	Perez Vico and Hallonsten (2019); Åström et al. (2011), Riksarkivet (2024)
Sveriges innovationsmyndighet	VINNOVA	2001		Promotion of sustainable development through the provision of innovation finance	VINNOVA (2022); Sveriges Riksdag (2009)
Related agencies					
Svensk uppfinnarkontoret	SUK	1947	1968	General support for inventors, check inventions, informations on patenting	Riksarkivet (2024)
Malmfonden		1961	1971	Support research and development in the scientific and technical sector with industrial connections; Projects were transferred to the STU after its establishment in 1968	Riksarkivet (2024)
Stiftelsen för exploatering av forskningsresultat	EFOR	1963	1968	Mediation of research results	Riksarkivet (2024)
Institutet för nyttiggörande av forskningsresultat	INFOR	1964	1968	Further development of research findings and inventions for industrial use	Riksarkivet (2024)
Fond för skeppsteknisk forskning	FST	1970	1978	Marine technology	Riksarkivet (2024)
Statens Industriverket	SIND	1973	1991	Promote industrial development and finance regional political development	Nationalencyklopedin (2023)
Energy related agencies					
Statens råd för atomforskning		1950	1976	Nuclear research	Riksarkivet (2024)
Värmeforsk		1968	2015	Finance and direct research in the fields of combustion, heat and environmental technology	Nationalencyklopedin (2023)
Energiforskningsnämnden	EFN	1982	1990	Long-term energy related research; function taken over by Statens energiverk in 1990	Nationalencyklopedin (2023)
Statens Energiverket	STEV	1983	1991	Administration of Swedish energy policy	Nationalencyklopedin (2023)
Energimyndigheten		1998		Promote transitions towards a sustainable energy system, research in fuel, renewable energy sources, green technology and international climate collaboration	Energimyndigheten (2023)

Elforsk			1993	2015	Research and development company of Swedish electrical companies	Energiforsk (2023)
Fjärrsyn			2006	2015	Research on district heating	Energiforsk (2023)
Svenskt Gastekniskt Center	SGC		1990	2015	Promote research on renewable gas from decomposition and gasification	SGC (2023)
Energiforsk			2015		Coordination and promotion of energy research	Energiforsk (2023)
Research councils						
Vetenskapsrådet	VR		2000		Largest governmental research funding body in Sweden with a budget of almost 8 billion, promotion of research in all scientific areas	Vetenskapsrådet (2022b); Sveriges Riksdag (2000), Nationalencyklopedin (2023)
Statens kommitté för byggnadsforskning			1942	1953	Building sector	Riksarkivet (2024)
Statens tekniska forskningsråd			1942	1968	Technical research finance, no support for applied research	Riksarkivet (2024)
Medicinska forskningsrådet	MFR		1945	2000	General and militaristic medical research	Riksarkivet (2024)
Skogs- och jordbruksforskningsrådet	SJFR		1945	2000	Research in agriculture and forestry	Riksarkivet (2024), Nationalencyklopedin (2023)
Statens naturvetenskapliga forskningsråd			1946	1976	Support scientific publications	Riksarkivet (2024)
Statens råd för samhällsforskning			1947	1976	Social science research	Riksarkivet (2024)
Statens nämnd för byggnadsforskning			1953	1960	Building sector	Riksarkivet (2024)
Statens humanistisk forskningsråd			1959	1976	Humanistic research	Riksarkivet (2024)
Bygghforskningsrådet	BFR		1960	2000	Promote research in community planning and the building sector	Bygghforskningsrådet (2016), Riksarkivet (2024)
Humanistisk-samhällsvetenskapliga forskningsrådet	HSFR		1976	2000	Promote and initiate research in social science, humanities, law, and religious studies	Nationalencyklopedin (2023), Vetenskapsrådet (2022b)
Naturvetenskapliga forskningsrådet	NFR		1976	2000	Natural science and mathematic basic research	Nationalencyklopedin (2023), Vetenskapsrådet (2022b)
Forskningsrådsnämnden	FRN		1977	2001	Support research and information on research; promote collaboration between research institutions	Nationalencyklopedin (2023)
Teknikvetenskapliga forskningsrådet	TFR		1990	2000	Technologic base research and research training; preference for projects promoting international collaboration	Riksarkivet (2024)
Forskningsrådet för hälsa, arbetsliv och välfärd	FORTE		2000		Research on health, worklife and welfare, annual budget of 800 million SEK	FORTE (2023)

Statligt forskningsråd för hållbar utveckling	FORMAS	2009		Research and innovation funding in environmental, agricultural science, spatial planning; Aiding Sweden in its effort to achieve the environmental targets	FORMAS (2023); Regeringskansliet (2009)
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Further funding bodies contained in SWECRIS					
1953 års fond		1953	1964	Support of poor students at Lund and Malmö university	Riksarkivet (2024)
Hjärt-lungfonden		1904		Founded as Swedish National Anti-tuberculosis association. Today general research in the field of cardiovascular diseases	Hjärt-Lungfonden (2023)
Ragnars Söderbergs Stiftelse		1960		Early career support for scientists in economics, medicine, and law	Ragnar Söderbergs Stiftelse (2023)
Familjen Kamprads Stiftelse		2011		Entrepreneurship, sustainability, and elderly care	Familjen Kamprad Stiftelse (2026)
KK-Stiftelsen		1994		Foster Sweden's academic competitiveness, academia-industry collaborations	KK-Stiftelsen (2026)
Naturvårdsverket		1994		Environmental protection	Naturvårdsverket (2026)
Statens Geotekniska Institut	SIG	1944		Promote geotechnical research in Sweden. Its research is of special importance for the construction sector.	SIG (2023)
Östersjöstiftelsen		1994		Development in Eastern Europe and the Baltic region	Östersjöstiftelsen (2023)
Karolinska Institutet		1810		Medical education and research	Karolinska Institutet (2026)
Institutet för arbetsmarknads- och utbildningspolitisk utvärdering	IFAU	1997		Research on labor market and education policy, annual budget of 6 million SEK	IFAU (2023)
Rymdstyrelsen	SNSB	1992		Space research and space applications	Wormbs and Källstrand (2007)
Stiftelsen Riksbankens Jubileumsfond	RJ	1964		Promotion and support of humanistic and social science research; Increasing focus on supporting of long term projects and international collaborations	Riksbankens Jubileumsfond (2017)
Other agencies					
Forskningsbiblioteksrådet	FBR	1965	1979	Provide information for research and development	Riksarkivet (2024), Nationalencyklopedin (2023)
Kungliga biblioteket		1968		Preservation and digitization of information in written, audio, and virtual form; Partially responsible for DFIs operations since 1988	Nationalencyklopedin (2023)
Statens råd för vetenskaplig information och dokumentation	SINFDOK	1968	1979	Provide information for research and development	Nationalencyklopedin (2023), Riksarkivet (2024)

Delegation för rymd- verksamheten	SBSA	1972	1992	Space research and space applica- tions	Wormbs and Källstrand (2007)
Biblioteks- och doku- mentationssamverkan- skommittén	BIDOK	1975	1979	Provide information for research and development	Riksarkivet (2024), Nationa- lencyklopedin (2023)
Delegationen för veten- skaplig och teknisk in- formationsförsörjning	DFI	1979	1988	Provide information for research and development	Riksarkivet (2024), Nationa- lencyklopedin (2023)

Paper III



Quantifying the brokerage power of Swedish innovation agencies, 1970–2021.*

Johanna Fink [†]

August 20, 2026

Abstract

Collaborative innovation has emerged as a way to share risks and costs associated with the innovation process. However, identifying and establishing contact with suitable collaboration partners proves challenging. To overcome this barrier, knowledge brokers, such as innovation agencies or universities, can step in to bridge contacts between innovative firms. This paper provides a long-term case study, estimating the brokerage power of Swedish innovation agencies using indicators from social network analysis. Additionally, the paper addresses the question whether collaborations involving innovation agencies differ from those established in their absence, based on a probabilistic regression model. To the author's best knowledge, this study provides the first quantitative assessment of the brokerage power of an innovation agency. Sweden is of particular interest because it ranks among the world's most innovative countries and was among the first to establish a second-generation innovation agency focused on promoting applied research. Data for the analysis is obtained from SWINNO, a database of significant Swedish innovations (1970–2021), which has been linked to a database over public innovation funding in Sweden (1968–2023). The sample consists of 1,392 innovative firms that engage in the development of collaborative innovations. Two dimensions of innovation agency involvement are considered: (1) direct provision of public funding, and (2) knowledge exchange through public funding applications. The results reveal that Swedish innovation agencies yield substantial brokerage power, being in direct contact with 40-70% of innovative firms, and intermediaries for 40-80% of potential collaborators. Moreover, collaborations brokered by innovation agencies are more likely to be associated with the emergence of local clusters, collaborations between firms differing in public ownership and initial contacts. Although the study does not directly identify network additionality, the results suggest that innovation agency involvement is associated with the formation of otherwise unlikely partnerships.

JEL classification: O30, O38, L38

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1 Introduction

The perception that novel technology is developed by the efforts of genius individuals, famously propagated by Joseph Schumpeter (1911), is no longer in line with reality. Since Schumpeter voiced his view in the early 1900s, major technological developments can no longer be accredited to single individuals, but rather research teams involving multiple organizations and hundreds of individuals (Dong et al., 2017). Among the most significant examples for this development is the Apollo program, involving hundreds of universities, 20,000 industrial companies, and 400,000 individuals (Gisler and Sornette, 2009). On this background, an extensive literature on collaborative innovation¹ has emerged in recent decades, (Burt, 1992; Roberts, 2000; Torfing, 2019; Acemoglu et al., 2016; Fleming and Marx, 2006; Nassani et al., 2022).

Collaboration across firm and organization borders generates several benefits for the involved parties (Burt, 1992; Roberts, 2000). It allows for pooling of resources, including contacts, knowledge and finances, increasing the scope of innovation projects. Moreover, collaborators can share risks and costs associated with the innovation process, reducing impediments to invest in potentially high yielding but costly technologies. Despite all these benefits, collaborative innovation is not feasible for all companies. Firms need to have sufficient information on others to identify firms that are interested in similar projects, being considered trustworthy, while providing complementary skills and resources (Kauffeld-Monz and Fritsch, 2013). Of special interest is the connection of knowledge producing and knowledge using entities, such as research institutions and manufacturing companies. Small and recently established firms face particular challenges since they seldom have an extensive net of business contacts or acquired the reputation of being a reliable business partner (Batterink et al., 2010).

This offers a role for knowledge brokers, highly connected and trusted entities that act as a go-between for innovative companies and organizations (Lomas, 2007). Knowledge brokers have a deep understanding of stakeholders, innovative, and decision-making environments, allowing them to promote the spread of relevant information and knowledge within their network, and creating a forum where knowledge users and producers can interact (Kauffeld-Monz and Fritsch, 2013; Bornbaum et al., 2015). There exists no formal limitation on who can classify as a knowledge broker in a sense of ownership status or network

¹Innovations are generally defined as new products or processes that have been commercialized, thus, put to economic use (Oslo Manual, 2005, p. 46). Some definitions take their collaborative dimension into account. Chaminade et al. (2018, p. 1) define and innovation as "an interactive process where different kinds of knowledge are combined through communication within and across organizational borders."

function. Previous research indicates that this position can be claimed by public, private, and independent entities. Moreover, actors within the network can fulfill their role as producers and users of knowledge simultaneously to acting as a network broker.

In Sweden, ranking among the most innovative countries in the world (Dutta et al., 2023; EU, 2023; Eurostat, 2022), the country's first central innovation agency STU (*Styrelsen för teknisk utveckling*)², embraced this role and considered itself as a network broker. Weinberger (1997) paints a picture of STU like a "spider in its web", using its network position to orchestrate the formation of contacts between innovative firms and leading research groups in Sweden. While the Swedish innovation system underwent major restructuring since STU was dissolved in 1991, its predecessors followed in its footsteps in terms of fostering collaborative innovation (Eklund, 2007; Arnold and Barker, 2022). Moreover, several policies have been implemented to support the emergence of innovations between partners unlikely to collaborate with one another, such as public-private partnerships, firms differing in size, and within specific sectors (Sveriges Riksdag, 1991; Vinnova, 2021; Energimyndigheten, 2019; Hall, 2019). While existing studies focus primarily on the question how innovation agencies managed to orchestrate the emergence of innovation, providing case studies as examples, less emphasis has been placed on quantifying their impact of on the creation of collaborations. Furthermore, the question emerges whether collaborations involving innovation agencies resemble those that do not or if they rather foster collaborations that would be unlikely otherwise. The latter would be indicative for the existence of network additionality (Radicic and Pugh, 2017).

This paper aims to contribute to the debate around network brokerage and network additionality, by providing a long-run case study based on the brokerage power of Swedish innovation agencies between 1970 and 2021. The study aims to address two dimensions: (1) quantifying the brokerage power of innovation agencies and (2) identifying differences in collaborator characteristics across collaborations involving and not involving innovation agencies, applying social network analysis and a probabilistic regression model. Two dimension of innovation agency involvement are considered, direct provision of public funding, and knowledge exchange through public funding application. Data is obtained from SWINNO, a database over significant innovations in Sweden (Sjöo et al., 2014; Kander et al., 2019; Torregrosa-Hetland et al., 2019; Taalbi, 2017), linked to a database on public innovation funding in Sweden (Fink and Taalbi, 2024; Fink and Torregrosa-Hetland, 2026), allowing for a long-term analysis of collab-

²STU was established in 1968 and operated until 1991, when it was integrated into NUTEK (Arnold and Barker, 2022).

orative and funding patterns across time. The sample studied consists of 1,392 innovative firms that engage in the development of collaborative innovations between 1970 and 2021.

The remainder of the paper is structured as follows: the second section summarizes previous research on the topics of brokerage power and network additionality. Data and methodology are presented in the third and fourth section. The fifth section presents the empirical results, followed by a discussion and concluding remarks.

2 Brokerage power and network additionality

2.1 Network brokerage

Brokerage can be defined as a process *"by which intermediary actors facilitate transactions between actors lacking access to or trust in one another"* (Marsden, 1982, p. 202). Thus, a brokerage relationship involves at least three different actors, out of which two are initially only indirectly connected to one another (Gould and Fernandez, 1989; Kauffeld-Monz and Fritsch, 2013). Brokers simultaneously send and receive resources, such as knowledge and financial resources, through the network (Burt, 1976; Galaskiewicz and Krohn, 1984). Lomas (2007) and Expósito-Langa et al. (2026) emphasizes the need of brokers to have a deep understanding of the involved parties, and be trusted and respected by the parties that they plan to connect to one another.

The majority of past quantitative studies have focused on identifying network brokers from a structural perspective (Kwon et al., 2020; Kauffeld-Monz and Fritsch, 2013). This ties into the literature on structural holes, pioneered by Granovetter (1973) and Burt (1992). In order to maximize information access while minimizing resources and efforts to maintain contacts, firms should maintain few but non-redundant contacts. Non-redundant contact are those which have neither direct nor indirect connection with other contacts of the central firm. Thus, the firm in question acts as a structural hole connecting two other wise unconnected parts of the network.

Nonetheless, the assumptions that firms benefit the most from maximizing their indirect contact was received critically. While direct and indirect ties both benefit the innovative capacity of firms, they are not simply substitutable (Ahuja, 2000). Direct collaborations provide information and financial resources, while indirect ties are exclusively information sources. Moreover, benefits from forming additional indirect connections is decreasing due to the risk of information overflow. Studies on network brokerage focus primarily on direct ties to determine brokerage power, since they focus on identifying cases where knowledge brokers were directly engaged in creating network ties

between their direct contacts (Kauffeld-Monz and Fritsch, 2013; Kwon et al., 2020). Moreover, Burt (2007) finds no evidence that knowledge brokers benefit from fostering indirect ties.

A number of recent studies have investigated the brokerage position of knowledge brokers in innovation networks from a quantitative perspective. Kauffeld-Monz and Fritsch (2013) study regional innovation networks in economically disadvantaged areas in Eastern Germany between 1999 and 2004. The study identifies universities and research institutes as the most important knowledge brokers, highlighting the importance of knowledge producers in the innovation network.

Cvitanovic et al. (2017) investigate the effectiveness of knowledge brokers in connecting scientists with decision makers based on a case study on Australia's largest research organization CSIRO, combining social network analysis with qualitative interviews. The results reveal that the CSIRO creates an increasingly dense network over the observation period. Moreover, study participants reported that contact with CSIRO improved their understanding of decision-making processes and potential collaborators.

A Dutch study investigates brokerage in the design and high-tech industry (Kirkels and Duysters, 2010). Participants were asked to indicate their most important business contacts, and the nature of their relationship to one another. The results reveal that actors in the science and non-profit sectors are in the most central brokerage positions.

Expósito-Langa et al. (2026) investigate network brokerage in a cluster of firms in the Valencian toy valley. While previous literature focuses much on the structural position to determine a firm's brokerage position, the authors findings highlight the need for absorptive capacity, institutional linkages, and contacts to firms and organizations outside the local cluster.

What all these studies have in common is that they identify knowledge producers as the most important network brokers, are case studies conducted over short periods of time, and based on survey data. Thus, they do not allow for the observation of long-term dynamics in brokerage, such as shifts in macroeconomic conditions, and the persistence of brokerage relationships (Kwon et al., 2020; Expósito-Langa et al., 2026). Further, several of these studies focus on a single sector, limiting possibilities to extrapolate the studies results to other parts of the economy (Kirkels and Duysters, 2010; Expósito-Langa et al., 2026). Most importantly, neither of these studies investigates the role of public innovation agencies as knowledge brokers.

2.2 Network additionality

The notions that markets are most efficient when left to themselves has been challenged in the context of innovation development since the late 1950s (Nelson, 1959; Arrow, 1962). Privately firms generally underinvest in R&D since they do not take positive externalities from their own innovation activity into account. Thus, a growing bodies of research addresses the question how governments can foster innovation activity (Bloch and Graversen, 2012; Mazzucato, 2013, 2016).

The additionality literature is centered around the idea that public policy is effective if it creates something that would not exist in its absence. Three types of additionality are distinguished (Falk, 2007): Input additionality addresses the question whether public investments incentive additional private investments or rather replace them (Bloch and Graversen, 2012; Zúñiga-Vicente et al., 2014). Output additionality is concerned with the question whether providing public funds generates additional outputs, such as additional innovations and patents (Lerner, 1999; Howell, 2017). Finally, behavioral additionality arises if firms receiving public support change their innovation behavior. According to Cameron et al. (2005), behavioral additionality might take place even if neither evidence for input nor output additionality can be detected. Network additionality falls into the latter category. It is particularly concerned with the question whether public policy affects collaboration behavior. Previous studies have focused on organizational learning in firms and innovative behaviors among SMEs (Clarysse et al., 2009; Berrutti and Bianchi, 2020; Bergman et al., 2010; Caloffi et al., 2018).

Several studies identify collaborator pairs with heterogeneous or complementary characteristics as inductive to radical innovation, which are of special interest for policy makers through their impact on economic growth and social welfare (Filippetti and Zinilli, 2023; Kang and Hwang, 2016; Burt, 1992). Within diverse collaborations, participants must balance the collaborating firms' visions of the final product and the combinations of their complementary skills and characteristics (Burt, 1992).

A few recent studies investigate innovation networks created through public funding provision. Kang and Hwang (2016) focus specifically on the innovation network created by European Union (EU) funding for renewable energy technologies. The study covers data between 2003 and 2013, which is aggregated into two time periods. The innovation network is characterized by local clusters that become increasingly integrated over time. However, the structure of the network is deemed as ineffective as firms engaging in complementary activities, namely knowledge use and knowledge production is limited. To address these inefficiencies, the authors call for knowledge brokers to connect firms with

complementary skills.

Min et al. (2020) evaluate the impact of public funding on innovation efficiency in South Korea. The study focuses on identifying drivers of inter-regional disparities in innovation efficiency. According to the study results, commercialization efficiency is highest in regions with large networks, while technological efficiency is highest in regions with high levels of public involvement. To maximize the potential of regional innovation projects, the authors recommend the simultaneous adoption of policies promoting public R&D expenditure and network building.

Cooperation additionality arising from the provision of public R&D funding is studied by Wanzenböck et al. (2013). Participating firms are asked whether they created contact with new partners due to the provision of public R&D support programs, or when collaboration is continued after the publicly funded projects is completed. The study's findings suggest, that cooperation additionality is lower among highly innovative firms, established in the field, as they are most likely already connected with relevant partners. In consequence the paper suggests that public funding is best channeled towards less innovation intensive, newly established firms.

Both studies take a longitudinal approach to observe changes in network over time. Nonetheless, neither of these studies covers more than a decade, leaving room for studies spanning multiple decades. Moreover, Kang and Hwang (2016) specifically voice the need for knowledge brokers to connect suitable collaboration partners, highlighting the need for additional research in this area.

2.3 Swedish innovation agencies as network brokers

Historically, public-private partnerships played a central role in fostering economic development and the diffusion of modern technology in Sweden (Fridlund, 1993; Enflo and Söderström, 2024). This was achieved through the provision of basic infrastructure, such as telegraph lines, electricity grids, and railways, which were developed through a long-term collaborations between a government agency and a private company. Fridlund (1993) coins this type of relationship as a *development pair*. Examples of development pairs include the State Railways (*Svenska järnvägar* – SJ) and ASEA (*Allmänna Svenska Elektriska Aktiebolaget*), the Power Board and (once again) ASEA, as well as the Swedish Telecom and Ericsson.

Despite successful collaboration in the past, the concept of the development pair became obsolete during the 1950s. After a disagreement over nuclear power generation between ASEA and the Swedish Power Board (Fridlund, 1993), their collaboration has been limited to a joint R&D company. Around this time alternative types of public incentives for fostering innovation activity grew in

importance. Among others the provision of public funding for applied research. The role of Swedish innovation agencies as network brokers and general facilitators of collaborative innovation has been investigated in multiple qualitative studies. Of special interest is the doctoral dissertation by Hans Weinberger (1997) "Nätvärksentreprenören", in which the author analyzes the establishment of the first Swedish innovation agency STU, and its emergence into a network broker in meticulous detail. Eklund (2007) investigates the debate around public innovation funding in Sweden during the 1990s, resulting in the establishment of the incumbent Swedish innovation agency VINNOVA. The remainder of this section presents the main results of these studies integrated into an historical overview of Swedish innovation agencies.

Fostering collaborative innovation has been among the responsibilities of the first Swedish innovation agency STU since its foundation in 1968 (Sveriges Riksdag, 1968).

*"Apart from funding, STU should conduct certain service activities, among others guidance for inventors, researchers, and dissemination of research results. STU should have a planning and coordinating function regarding international technical collaboration, information, documentation, as well as certain research stations."*³

However, STU did not fulfill this function for the first 10 years of its existence as it struggled with settling conflicts between departments and building up the capabilities needed to effectively promote innovation activity in Sweden (Arnold and Barker, 2022; Weinberger, 1997, p. 385–395). During this time STU faced substantial critique, especially from opposition parties. According to Arnold and Barker (2022), STU's survival during the early years of its existence was tied to the absence of political power shifts.

Only after a public investigation conducted in 1977, did STU start to tap into its potential as a knowledge broker (Weinberger, 1997, p. 27, 427–432). The investigation in question describes STU's comparative advantage in terms of competence and contacts as follows (SOU, 1977, p. 224–225):

STU has an outstanding potential network of contacts with authorities, companies, the research community and other public and private bodies with expertise in different areas. STU has greater knowledge of and better contact with the areas of activity of companies and authorities, compared to the research community. Compared to the companies and innovators receiving support, STU has greater knowledge and better contact with research and social sectors, etc. Compared to its main recipients and client

³Own translation of government bill 1968:68.

*categories, STU thus has considerable comparative advantages in these respects. In short, STU has a unique and central position in terms of expertise and contacts. Probably no other private or public organization even has a nearly similar position in the field of technology development.*⁴

Given the amount of knowledge on the interest and needs of both types of partners, STU was sitting like a "spider in it's web", creating connections between firms interested in the same type of products, but had access to complementary resources and skills. A government report from 1986 describes the triangular type of collaboration fostered by STU during this period (FRN, 1986, p. 28–31), involving apart from STU, industry representatives and research institutions, primarily technical universities (Schilling, 2005, p. 83–84).

Weinberger (1997, p. 441–454, 457–460) provides two examples for STU promoting collaboration between scientists and major companies in Sweden in the field of material science in connection to the introduction of framework programs (*ramprogram*), providing provided clear long-term goals for technical development (Weinberger, 1997, p. 427–432). A major challenge when formulating framework programs was to take both interests and needs of universities and industries into account, as well as identifying areas of particular interest. While researchers were particularly focus on long-term knowledge gains, industry representatives opted for tackling concrete issues that could be addressed within a short time frame (Weinberger, 1997, p. 441–454). Instead of trying to balance these interests by themselves, STU invited leading scientist from Sweden's technical universities and industry representatives to find a mutually beneficial compromise. STU remained in the background during these discussions but set clear time frames and brought in new representatives on a regular basis to keep the discussions dynamic and ensure that participants produced concrete ideas and proposals.

In material science STU brought together researches from the countries leading technical universities, Lund, Gothenburg, and Linköping, as well as industry representatives from Alfa Laval, Atlas Copco, Jernkontoret, Volvo, Asea, Sandvik, Ericsson, and Keno Gard (Weinberger, 1997, p. 441–454). Even international partners were invited, namely the Norwegian Central institute for industrial research and Xerox from California. To design the framework program in the sub-field of bio-compatible materials, STU contacted scientists from Linköping, Lund, and Chalmers, as well as Bofors and Nobel Pharma. Bio-compatible materials are protein resistant and, thus, suitable for applications in the medical field and food industries. Weinberger (1997, p. 457–460) explicitly names a few public funding application and research outputs that can be found in the

⁴Own translation of the government's public investigation 1977:64.

innovation and public funding data presented in the following section.⁵

The focus on fostering collaboration was maintained after STU was replaced by NUTEK (*Närings- och teknikutvecklingsverket*) in 1991, and when the Swedish Governmental Agency for Innovation Systems (*Verket for Innovationssystem – VINNOVA*) took over in 2001. Promoting the development of SMEs was one of the central responsibilities for NUTEK (Sveriges Riksdag, 1991). NUTEK actively attempted to foster contacts between SMEs, universities, and larger companies. However, these efforts were hampered by the limited capacity of SMEs for knowledge absorption (Eklund, 2007, p. 78). An issue identified as crucial in innovation network literature (Expósito-Langa et al., 2026).

NUTEK's successor VINNOVA even had the innovation systems concepts in its name (Eklund, 2007, p. 11). The innovation system concept was developed by Freeman (1982a) and Lundvall (1985) during the 1980s and emphasizes the importance of collaboration and exchange between actors and institutions, involved in innovation development. In correspondence to this, the government proposal outlining VINNOVA's functions and responsibilities lists the fostering of collaborations between firms and universities, participation in EU programs, and support for SMEs, among VINNOVA's central responsibilities (Sveriges Riksdag, 2000, p. 38). Under current legislation collaborative innovation are still treated preferentially, especially those involving SMEs and research institutions (Vinnova, 2021; Energimyndigheten, 2019).

While these studies provide detailed case studies and insight into the channels that innovation agencies used to promote collaborative innovation, neither of them quantifies the position of Swedish innovation agencies as network brokers. Moreover, existing literature does not indicate what types of collaborator were promoted outside of a few case studies.

3 Data

3.1 Data Sources

Data on innovations is sourced from the SWINNO database, capturing significant innovations in Sweden between 1970 and 2021 (Sjöö et al., 2014; Kander et al., 2019). SWINNO has been constructed based on the Literature Based Innovation Output (LBIO) approach. This approach entails the screening on trade journals, which aim to report on technological developments in their respective fields, for information on recently commercialized innovations. Innovations

⁵Bofors commercialized a bio-compatible dental prothesis in 1984, included in SWINNO under the id 8264001. Nobel Pharma applied successfully for the development of prosthetic materials in 1982. Linköping University, and Lund University applied multiple times for investigating bio-compatible and titan-based materials in the early 1980s.

identified in this way are considered as significant since the editors are knowledgeable in their field of expertise and therefore able to identify the product introductions and developments with high degrees of novelty and economic significance. The latest release of SWINNO contains 4,838 innovations, commercialized between 1970 and 2021. For each innovation, the database contains a description, information on innovating firms, the year of commercialization, product codes, classification of innovations, and funding sources. A total of 948 innovations in SWINNO, corresponding to 19.6%, have been reported as being developed in collaboration. For collaborators information on their names, location on the national level, type, and firm id is included. Collaboration data from SWINNO has been analyzed in previous network studies (Taalbi, 2017; Chaminade, 2022; Bucaioni et al., 2025; Kreutzer and Taalbi, 2026).

Despite the existence of a funding variable in SWINNO, studies by Torregrosa-Hetland et al. (2019) and Fink and Taalbi (2024) find that information on public funding in SWINNO is severely under-reported by approximately a factor of four. Therefore, an additional source for public funding data is needed. This study will make use of the Public Funding Database capturing approved Swedish public funding projects between 1968 and 2023, to gain more insight into the actual extent of public funding in innovation activity.

The Public Funding Database has been constructed by Fink and Taalbi (2024) and Fink and Torregrosa-Hetland (2026) and compiles data on public innovation funding between 1968–2023. Multiple data sources needed to be combined since the Swedish public funding landscape has undergone frequent restructuring over the study period and data on public funding projects is highly fragmented (Åström et al., 2011; see Section 2.3). The database does primarily contain information from Sweden’s major innovation agencies that were active during the study period, STU, NUTEK, and VINNOVA. This is complemented by data from the Malmfonden, which existed in parallel with STU between 1968–1971, as well as the Swedish Energy Agency (*Energimyndigheten*), which took over responsibility for the development of energy innovations in 1998 (Riksarkivet, 2022; Arnold and Barker, 2022).

Table 1 presents all different data sources and the number of approved and non-approved projects included in the Public Funding Database. It contains a total of 107,293 public funding projects from seven different data sets. The resulting database contains information on names of involved firms, approval status, descriptions, approved amounts, project start-, end-, and decision dates, and project ids. For STU, and STINS information on applied amounts, and non-approved projects is included.

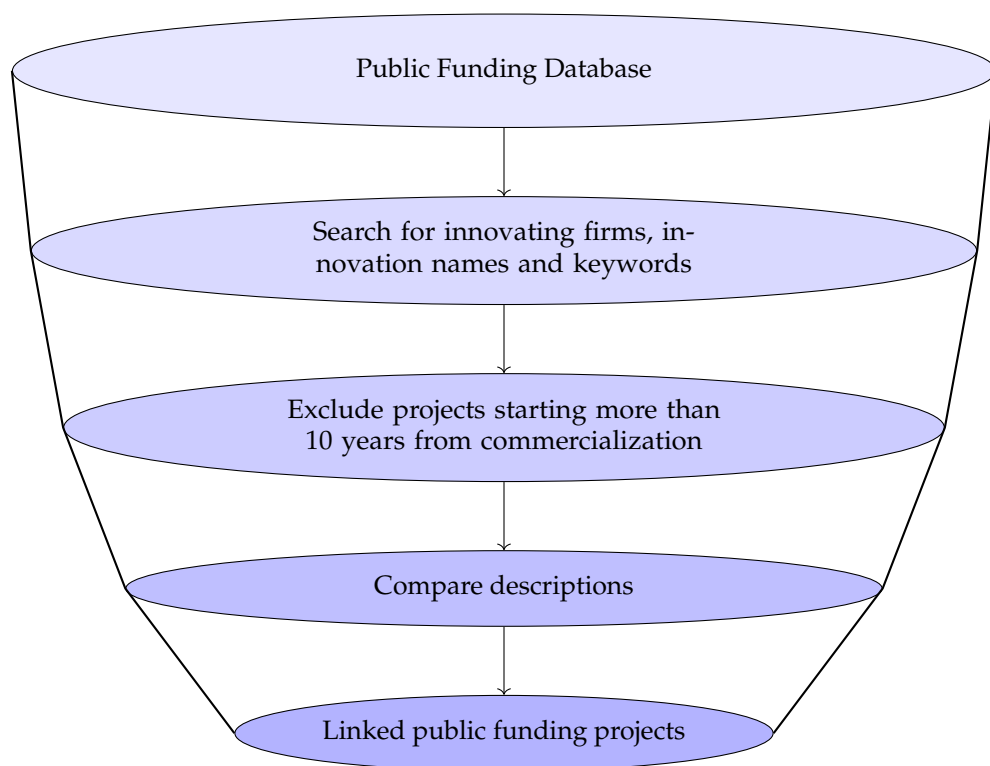
The studies by Fink and Taalbi (2024) and Fink and Torregrosa-Hetland (2026), are the first to present the Public Funding Database, as well as an approach to directly link innovation in SWINNO to projects in the Public Funding Database.

Table 1: Public Funding Database

Source	Time	Approved	Non-approved	Note
Malmfonden	1968–1970	104		Riksarkivet
STU	1968–1978	6,925	4,592	Riksarkivet
STINS	1979–2001	35,843	20,341	Riksarkivet
Energimyndigheten	1998–2008	5,268		Energimyndigheten
VINNOVA	2001–2009	5,964		VINNOVA
SWECRIS	2007–2023	53,189		Vetenskapsrådet (2022)
Total	1968–2023	107,293	24,933	

Note: STINS is a digital database containing public funding projects from STU (1979–1991), as well as NUTEK (1991–2001). SWECRIS combines public funding projects from VINNOVA, Energimyndigheten, and the Swedish Research council (2007–2023).

Figure 1: Linking process



The steps taken to identify and evaluate potential matches is presented in Figure 1. For each innovation in SWINNO a subset of potential matches from the Public Funding Database is created. The Public Funding Database is searched for projects involving the developing firm(s), and those containing the innovation name and keywords from the description. Further, potential matches

must be developed within a time frame of 10 years around commercialization. For example, an innovation commercialized in 1985, public funding projects between 1975 and 1995 are considered. All remaining potential matches are manually screened to ensure that the descriptions of the innovation and public funding projects refer to the same innovation. In total 30.9% of the 948 collaborative innovations can be directly linked to approved public funding projects, compared to 24.1% for innovations in general.

3.2 Network construction

The network in this study is constructed by combining collaboration data from SWINNO and public funding applications from the Public Funding Database. Individual firms and organizations are represented as nodes while any exchange of resources is represented as ties.

Data on collaborative innovation is obtained from the SWINNO database. In total 948 SWINNO innovations are developed in collaboration involving 1,390 innovative firms. Since several of these collaborations involve more than two collaborators, a total of 2,039 collaborator pairs can be identified.

Information on contacts between these innovative firms and the innovation agencies is obtained from the Public Funding Database. 601 corresponding to 43% of the innovative firms are represented in both SWINNO and the Public Funding Database, indicating that they are in direct contact with innovation agencies.

It should be noted that merely four innovation agencies are considered for network construction, Sweden's main innovation agencies (STU, NUTEK, VINNOVA) and, Energimyndigheten, which took over responsibilities for funding energy related research in 1998 (Arnold and Barker, 2022). Data from Malmfonden is integrated with data from STU, since the agencies were fully integrated in 1971, merely one year after the start of the observation period (Riksarkivet, 2022).

Since the data set spans a total of 52 years, the long time frame of the study needs to be considered when conducting the analysis. It appears unreasonable to assume that a single collaboration between two companies during the 1970s or 1980s would increase their likelihood to engage in collaborative innovation development in the 2010s, given that they had no contact since. Similarly, innovation agencies would no longer be up-to-date on public funding applicants resources, and research interests after a few years. To account for this, ties between innovation agencies and firms, as well as between collaborators are dissolved 5 years after they are established.

Taken the entire observation period together, the final data set contains 1,394 nodes (firms and innovation agencies) connected by 21,446 ties. Both approved

and non-approved public funding projects are considered since either entail a knowledge exchange. For the following analysis the innovation network is broke down by year to allow for the observation of network characteristics across time.

It should be noted that collaboration data in SWINNO is underreporting actual collaborations, particularly when these involve universities during early stages of development (see Torregrosa-Hetland et al., 2019 and Kreutzer and Taalbi, 2026). For example, in the example of collaborations in bio-compatible materials, Weinberger (1997, p. 457–460) outlines that Bofors developed dental prosthetics in collaboration with researchers at Chalmers, resulting in the successful commercialization of a dental prosthesis in 1984 which is reported in the SWINNO database. Nevertheless, the involvement of researchers at Chalmers in the research and development process is nowhere mentioned in the database.

4 Methodology

4.1 Brokerage power of innovation agencies

This paper utilizes several concepts and measures from network literature. For clarification and especially readers unfamiliar with this field, central terms and concepts are introduced in Table 2. As collaborative innovations entail mutual exchange of resources and ideas, all definitions refer to an undirected network (Barabási, 2012, p. 30).

The papers by Kauffeld-Monz and Fritsch (2013) and Cvitanovic et al. (2017) provide a baseline on how to investigate the brokerage power of innovation agencies from a social network analysis perspective. Both studies base their estimation of brokerage power on the firms immediate contacts, presented in the ego-network. The ego-network contains only the firm or organization in question and its direct contacts, as collaborations effectively if they are in direct contact with both partners. Moreover, network brokers are defined as go-between partners. In this case they might even aid their indirect connections to build contacts with other firms in the network. In network terms the measures of primary interest are thus degree centrality and betweenness centrality. Degree centrality refers to the fraction of nodes in the network that is directly connected to the network broker, while betweenness centrality, is defined as the fraction of cases where the firm or organization is on the shortest parts between two firms (see Table 2).

One of the major aims of this study to estimate how many of the collaborations are likely to have been established with the help of innovation agency. Two dimensions are considered: recent contact with the innovation agencies and the provision of public innovation funding. First, by applying for public funding

Table 2: Central concepts from network analysis

Measure	Definition
Node	Single actor in a network. The total number of nodes is used as a measure for network size.
Link	Indicates a relationship between nodes.
Degree	Number of links connected to a single node.
Isolate	Node that has no link to any other component in the network.
Density	Number of realized links in the network divided by the potential number of ties.
Centrality	Most central or well-connected actors in the network.
Distance	Smallest possible number of links connecting two nodes. Also referred to as shortest path.
Diameter	Longest shortest path connecting two nodes in the network.
Component	Group of nodes that are at least indirectly connected to one another.
Ego-network	Network consisting of a central node (ego) and all its direct contacts. This includes ties between the ego's direct contacts.
Fragmentation	Share of nodes that are not part of the biggest component.
Homophily	Increased attachment probability between nodes with similar characteristics.
Dyad	Connection between two actors in the network.
Triad	Connection between three actors in the network.
Triadic closure	Likelihood of two indirectly connected nodes to form a direct link.
Small-worldness	Most nodes are not directly connected but are connected indirectly through a highly connected hub.
Structural hole	Node connecting otherwise separate parts of the network.

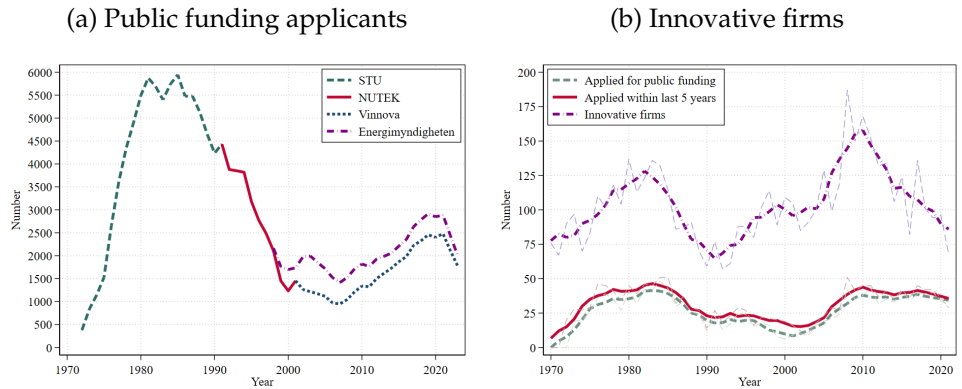
Source: Barabási et al. (2000), Bedru et al. (2020), Freeman (1982b).

firms provide information to innovation agency on their research and innovation interest. With access to this information, innovation agencies have the potential to bring together suitable innovation partners with access to complementary resources. In network terms this is measured as triadic closure. As discussed in Section 3.2, it is assumed that innovation agencies are up to date on a firm's innovation activity for 5-years following the application. This assumption is tested in Section 6. Second, innovations that have received public funding might have been of lower quality or not realized at all in its absence. Thus, there is a substantial probability that they would not have qualified to be included in the sample of significant innovation that this study is based on (Fink and Taalbi, 2024; Fink and Torregrosa-Hetland, 2026).

In case that a collaboration fulfills both criteria it is considered as the strongest contender for innovation agencies' involvement in the establishment of collaborator pairs. This definition taking both recent contact and direct financial assistance into account is central to the following analysis.

The number of contacts between innovation agencies and and innovative firms

Figure 2: Links to innovation agencies, 1970–2023 (5-year moving average)



Note: Observations for Energimyndigheten are stacked, over observations linked to NUTEK and VINNOVA.

are presented in Figure 2. Innovation agencies receive application from up to 6000 firms per year (see Figure 2a). This study focuses on a subset of innovative firms from the SWINNO database. 87 to 187 innovative firms are linked to innovations in the SWINNO database for each given year. Throughout the observation period approximately a third of these firms applies for public funding within a 5-year interval.

4.2 Fostering diverse collaborations

The second part of the analysis aims to identify differences in collaborations involving innovation agencies to those that do not. Evidence from network literature suggests that, firms tend to seek out well-connected collaboration partner that are similar to themselves. (Kang and Hwang, 2016; Fleming and Marx, 2006; Acemoglu et al., 2016). These phenomena are known as preferential attachment and homophily (Barabási and Albert, 1999; McPherson et al., 2001). Summary statistics presented in Table 3, suggest that homophily in firm size, ownership, and degree centrality are characteristic for the Swedish innovation network, while regional collaborations are unlikely to emerge. In case that innovation agency involvement is associated with unlikely collaboration we should expect lower homophily among collaboration partners, as well as an increased likelihood of regional collaboration.

Correlations between collaborator characteristics and innovation agency involvement are calculated based on a probabilistic regression model, similar to Nieto and Santamaría (2010). As presented in equation 1, the involvement of

innovation agencies in a collaboration IA_{ij} , is correlated with a set of control variables X_{ijkt} . i and j refer to Firm 1 and Firm 2 involved in the collaboration, k is the innovation, and t is the innovation's commercialization year. Both dimensions of innovation agency involvement, recent contact and the provision of financial support, are considered separately and in combination.

$$Pr(IA_{ij} = 1|X_{ijkt}) = \alpha + \beta_1 Size_{i=j} + \beta_2 Location_{i=j} + \beta_3 Ownership_{i=j} + \beta_4 Degree_{i_{t-1}=j_{t-1}} + \gamma_{it} + v_{kt} + \tau_t + \epsilon \quad (1)$$

The independent variables of interest are matches in firm size $Size_{i=j}$, location $Location_{i=j}$, ownership $Ownership_{i=j}$, and degree $Degree_{i=j}$. Firm controls γ_{it} include firm size, public ownership, location on the regional level (*län*)⁶ and degree. Innovation controls v_{kt} are added to account for major innovations, patenting prior to commercialization, sector, as well as the commercialization year. τ_t consists of a set of time dummies for each 5-year period. The 1970s are considered as the baseline category. The construction of control variables is presented in greater detail in Section 6.

Summary statistics for the variables used in the probabilistic regression model are presented in Table 3. Apart from *degree* and *commercialization year* all variables are dummies and, thus, only vary between 0 and 1. The main independent variables are presented in the first four rows. In terms of firm size, ownership, and degree, two-thirds or more of collaborations emerge between firms with similar characteristics. Thus, the Swedish innovation network displays great signs of homophily. The only exception are collaborations between firms located in the same region, which merely occur in 19.5% of cases.

⁶It was necessary to collect additional data on firm location, since the location of collaborating firms in SWINNO is merely available on the national level (Sweden, Finland, Germany, US, etc.). Therefore I collected information on the location of collaborating Swedish firms based on firm names, firm websites, official registries, and web searches. The latter was of particular importance for firms that are no longer in existence.

Table 3: Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Match firm size	2,039	0.5787	0.4939	0	1
Match ownership	2,039	0.7548	0.4303	0	1
Match location	2,039	0.1947	0.3961	0	1
Match degree	2,039	0.8710	0.3353	0	1
Firm controls					
Degree	2,039	0.7038	2.5401	0	21
Small firm	2,039	0.3541	0.4784	0	1
Large firm	2,039	0.5179	0.4998	0	1
Public own.	2,039	0.1295	0.3358	0	1
Innovation controls					
Commercialization year	2,039	1998.44	15.20	1970	2021
High significance	2,039	0.3413	0.4743	0	1
Patented	2,039	0.0858	0.2802	0	1
Sector					
Consulting	2,039	0.0539	0.2260	0	1
Energy	2,039	0.0329	0.1783	0	1
Environment	2,039	0.0520	0.2221	0	1
Food	2,039	0.0329	0.1783	0	1
Information	2,039	0.0912	0.2880	0	1
Manufacturing	2,039	0.6258	0.4840	0	1
Medicine	2,039	0.0559	0.2298	0	1
Military	2,039	0.0029	0.0542	0	1
Transport	2,039	0.0525	0.2230	0	1
Location					
Blekinge	2,039	0.0461	0.2098	0	1
Dalarna	2,039	0.0216	0.1453	0	1
Gävleborg	2,039	0.0226	0.1485	0	1
Halland	2,039	0.0255	0.1577	0	1
Jämtland	2,039	0.0029	0.0542	0	1
Jönköping län	2,039	0.0294	0.1690	0	1
Kalmar	2,039	0.0088	0.0936	0	1
Kronoberg	2,039	0.0074	0.0855	0	1
Norrbottn	2,039	0.0363	0.1871	0	1
Skåne	2,039	0.1025	0.3034	0	1
Stockholm	2,039	0.2330	0.4228	0	1
Södermanland	2,039	0.0078	0.0883	0	1
Uppsala	2,039	0.0186	0.1353	0	1
Värmland	2,039	0.0162	0.1262	0	1
Västerbotten	2,039	0.0265	0.1606	0	1
Västernorrland	2,039	0.0186	0.1353	0	1
Västmanland	2,039	0.0177	0.1317	0	1
Västra Götaland	2,039	0.1486	0.3558	0	1
Örebro län	2,039	0.0064	0.0796	0	1
Östergötland	2,039	0.0692	0.2538	0	1

5 Results and discussion

5.1 Brokerage power of innovation agencies

This section aims to quantify the brokerage power of innovation agencies based on social network analysis. General summary statistics for the Swedish innovation network are presented in Table 4, in 5-year intervals. It should be noted that the network in 1970 is substantially smaller, in term of the number of nodes, compared to the following years since public funding data is only fully available from 1972 onwards.

Table 4: General network metrics, 1970–2021

Year	Nodes	Edges	Dens.	Avg. deg.	Avg. dist.	Comp.	L. Comp.	Fragm.	Diam.
1970	24	16	0.0580	1.33	1.80	9	5	0.7917	3
1975	221	273	0.0112	2.47	2.47	11	201	0.0905	4
1980	306	377	0.0081	2.46	2.55	22	256	0.1634	6
1985	377	520	0.0073	2.76	2.55	21	334	0.1141	6
1990	321	350	0.0068	2.18	2.41	18	283	0.1184	6
1995	282	382	0.0096	2.71	2.31	17	242	0.1418	4
2000	255	336	0.0104	2.64	2.86	29	197	0.2275	6
2005	245	322	0.0108	2.63	2.74	30	183	0.2531	7
2010	343	531	0.0091	3.10	2.78	30	274	0.2012	6
2015	347	489	0.0081	2.82	2.66	25	287	0.1729	6
2020	336	594	0.0106	3.54	2.69	19	292	0.1310	6
2021	334	588	0.0106	3.52	2.69	23	281	0.1587	6
2000	255	336	0.0104	2.64	2.86	29	197	0.2275	6
2005	245	322	0.0108	2.63	2.74	30	183	0.2531	7
2010	343	531	0.0091	3.10	2.78	30	274	0.2012	6
2015	347	489	0.0081	2.82	2.66	25	287	0.1729	6
2020	336	594	0.0106	3.54	2.69	19	292	0.1310	6
2021	334	588	0.0106	3.52	2.69	23	281	0.1587	6

The network is characterized by low fragmentation, and density, small diameter and average path length. These are indicators for small-worldness and the existence of a central hub, in this case the innovation agencies (Watts and Strogatz, 1998). There exists a supermassive component comprising 75-90% of all nodes from 1972 onwards. Within the supermassive component firms are on average less than 3 and no more than 7 steps away from one another. Moreover, the network is very sparse, as only 1% of potential connections are realized. Sparsity of innovation network is a common phenomenon. The network studied by Kang and Hwang (2016) is of a comparable size ($n=1,366-1,770$), and density varies between 0.012-0.019. Even in the substantially smaller network studied by Cvitanovic et al. (2017), containing merely 192 nodes, no more than 10.8% of potential connections are realized.

This corresponds to the visual presentation of the Swedish innovation network in Figure 3, containing decade-wise snapshots of the Swedish innovation net-

work. As indicated in the summary statistics, Figure 3 confirms the existence of a supermassive component, with the incumbent innovation agencies and after 1998 even Energimyndigheten at its center. The only exception is the innovation network from 1970 presented in Figure 3a, when public funding data is not yet fully available.

Table 5: Network metrics based on innovation agencies' ego-networks, 1975–2021

Year	Agency	Degree	Betweenness	Triangles	Clustering coeff.
1975	STU	0.8061	46	0.0042	0.0042
1980	STU	0.6887	37	0.0021	0.0021
1985	STU	0.7720	70	0.0024	0.0024
1990	STU	0.7721	22	0.0009	0.0009
1995	NUTEK	0.7247	45	0.0023	0.0023
2000	NUTEK	0.4446	23	0.0041	0.0041
2005	VINNOVA	0.3486	60	0.0132	0.0132
2010	VINNOVA	0.4806	119	0.0095	0.0095
2015	VINNOVA	0.5727	95	0.0056	0.0056
2020	VINNOVA	0.6141	140	0.0086	0.0086
2021	VINNOVA	0.5733	133	0.0092	0.0092
2000	EM	0.1883	10	0.0048	0.0048
2005	EM	0.2491	55	0.0174	0.0174
2010	EM	0.2135	71	0.0219	0.0219
2015	EM	0.1351	75	0.0278	0.0278
2020	EM	0.1715	94	0.0257	0.0257
2021	EM	0.1524	87	0.0275	0.0275

To further investigate the network position of innovation agencies, summary statistics of the ego-network are presented in Table 5. Of special interest is not only the brokerage position of the innovation agency but also the collaborations that emerge between its network contacts. As in Table 4, measures are presented in 5-year intervals. From 2000 onwards two rows are included per interval since responsibilities for innovation development in the energy sector are taken over by Energimyndigheten.

To illustrate developments over the observation period, Figure 4 contains longitudinal series indicating the fractions of direct and indirect ties of the innovation agencies, as well as measures of betweenness centrality and triadic closure. The share of direct ties is close to 70% between 1972 and the mid-1990s. Thus, innovation agencies are in direct contact with approximately 70% of innovative firms during a given year. The fraction of direct ties drops to around 45% for the main innovation agency after Energimyndigheten is established in 1998. Since Energimyndigheten took over responsibilities to support the development

of energy innovations, around 25% of firms are no longer in direct contact with the main innovation agency. These are most likely firms focusing on the development of energy related technologies. Example for this include Kvaerner, a supplier of offshore equipment, and MTAB, a transport company.

The share of indirect ties is between 75-90% throughout the observation period. Since Energimyndigheten, is part of the same component as NUTEK and STU, they also are indirectly connected to an identical fractions of actors in the innovation network.

Innovation agencies are intermediary contacts for 70-80% of firms before 1995. This value is similar to the most connected unit in the study of Kauffeld-Monz and Fritsch (2013)⁷. The graph displays similarity with the fraction of direct ties, dropping by about 0.4 around the establishment of Energimyndigheten. Towards the end of the observation period, it recovers to 0.6, three quarters of its pre-1995 value.

Triadic closure indicates how many of the innovation agencies direct contacts are connect to one another through engaging in collaborative innovation. As presented in Table 5, the number of realized triangles grows over the observation period from 46 to a maximum of 164 between 1975 and 2020 for the main innovation agencies. Nonetheless, since the network size also increases, the fraction of realized connections in potential connections never exceeds 1.5%. For Energimyndigheten it amounts to a maximum of 2.8% since it is merely connected to half of VINNOVA's direct ties. What should be considered here is that the development of a significant innovation is a rare event, especially when only considering collaborative innovations. Thus, a low clustering coefficient is expected in this network.

5.2 Collaborator characteristics

This section focuses on differences in collaborator characteristics between collaboration brokered by innovation agencies and those that were not. Of particular interest are collaborations where firms are similar in firm size, location, ownership, and connectedness.

Collaborations are considered to involve innovation agencies if they are (1) linked to an innovation that received public funding, and (2) emerges between two firms that applied for public funding within the past 5-years. Of special interest are (3) collaboration that fulfill both conditions, hence, they emerge between two recent public funding applicants and are linked to an innovation

⁷The most connected unit in the study by Kauffeld-Monz and Fritsch (2013) in terms of betweenness is located on 76.4% of the shortest path between individuals, while the average value amounts to 5.4%.

that received public support. The fraction in collaborations matching each of the three cases is presented in Figure 5.

The fraction of collaborations receiving direct public funding remains at around 40% during the 1980s and early 1990s, climbing to over 60% in the 2010s. The share of collaboration where both partners were in contact with the innovation agencies within the past 5 years remains quite consistently between 25-30%. 302 collaborations, corresponding to 21.95% of all collaboration meet both criteria and are thus the most likely candidates for collaborations established with the help of innovation agencies.

The results are presented in Table 6, displaying both the coefficients from the probit regression as well as the marginal effects. Regression results are presented for three groups separately, (1) collaborations linked to an innovation that obtained public funding (funded innovation), (2) collaborations where both partners applied for public funding within 5-years before commercialization (funding applicants), (3) collaborator pairs where both conditions (1) and (2) are fulfilled (both).

Table 6: Differences in collaborator characteristics

	Funded innovation		Funding applicants		Both	
	Probit	Marg. effect	Probit	Marg. effect	Probit	Marg. effect
Match firm size	-0.031 (0.628)	-0.010 (0.628)	0.095 (0.206)	0.022 (0.205)	0.000 (0.998)	0.000 (0.998)
Match location	0.083 (0.287)	0.027 (0.287)	0.251*** (0.003)	0.059*** (0.003)	0.238** (0.014)	0.039** (0.013)
Match ownership	-0.274*** (0.001)	-0.088*** (0.001)	-0.614*** (0.000)	-0.145*** (0.000)	-0.589*** (0.000)	-0.097*** (0.000)
Match degree	-0.381*** (0.001)	-0.122*** (0.001)	-0.612*** (0.000)	-0.144*** (0.000)	-0.661*** (0.000)	-0.109*** (0.000)
Constant	-0.562** (0.032)		-0.228 (0.408)		-0.922*** (0.009)	
Observations	2033	2033	2033	2033	2027	2027
Pseudo R-sq	0.163		0.143		0.207	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Innovation controls	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No

Notes:

*p<0.05; **p<0.01; ***p<0.001

The final two columns, displaying estimation results for collaboration that fulfill both criteria. Marginal effect are particularly large and highly significant for ownership and degree, amounting to -9.7% and -10.9%, correspondingly. Thus collaborations brokered by innovation agencies are particularly more likely to involve public-private partnerships and collaborations between central and peripheral actors. Moreover, innovation agency involvement is associated with

a 3.9% increased likelihood of local collaboration. Pre-signs of estimates are consistent across the specifications of innovation agency involvement. The only major difference is that location is insignificant under definition (1). Firm size is under no specification significantly correlated with innovation agency involvement. This result might be driven by lacking or ineffective incentives to involve SMEs during parts of the observation period (Arnold and Barker, 2022; Vinnova, 2021; Energimyndigheten, 2019; Eklund, 2007, p. 78). A potential explanation for this is the high correlation between public ownership and large firms. 75% of public innovative firms are classified as large, while this applies to merely 15% of private companies. To check whether this is an issue correlations between the four main variables have been conducted. The results are presented in Table 7. Several of the main independent variables are weakly correlated with one another. However, this is deemed as unproblematic since the amplitude of none of these correlations exceeds 0.2.

Table 7: Correlations between main independent variables

	Match firm size	Match location	Match ownership
Match location	-0.0596* (0.0071)		
Match ownership	0.1647* (0.0000)	-0.1401* (0.0000)	
Match degree	0.0273 (0.2184)	-0.0288 (0.1937)	0.1344* (0.0000)

The goodness of fit of the probabilistic regression is with 0.204 for (3) within the range of 0.2-0.4, considered good in social science literature (Hemmert et al., 2018).⁸ The fit is slightly worse under definition (1) and (2) falling between 0.142-0.164, strengthening the choice to use (3) as the main definition of innovation agency involvement.

Several robustness checks are conducted, testing the sensitivity of the regression results to alternative definitions of tie persistence, variations over time, macroeconomic conditions, and confirmed information on firm size and location (see Section 6). The results reveal that results are generally consistent.

Varying tie persistence has primarily an effect on illustration of the innovation network, and the size of the coefficients in the probabilistic regression model. However, since metrics for assessing brokerage power and the direction of the correlations in collaborator characteristics are consistent, the results of the presented analysis are deemed as robust to variations in tie persistence. Also

⁸Hemmert et al. (2018) give the reference of 0.2-0.4 being good, over 0.4 excellent.

when splitting regression results by decade no major changes in the direction and magnitude of estimates can be observed (see Table 15). Merely innovation precision and the model fit are slightly improved. The only noteworthy difference is that innovation agency involvement is significantly correlated with collaboration among firms differing in size during the 2010s, pointing to an improvement in incentives to promote these collaborations over recent years.

5.3 Local clusters

The estimation results reveal that collaborations between firms located in the same region (*län*) are correlated with innovation agencies involvement. This section takes a closer look at local collaborations involving innovation agencies, particularly during the 1980s (see Table 6 and Table 12). 397 collaborations can be identified where both collaboration partners are located in the same region, out of which 97 involve innovation agencies.

Stockholm, Västra Götaland, and Scania stand out in the emergence of regional clusters, accounting together for more than 70% of regional collaborations in the data set. This result comes unsurprising as these are the most populous regions in Sweden, accounting for a similar share of Swedish GDP (Nilsson et al., 2023), and according to Fitjar (2025), public and private R&D funding are strongly concentrated in regions with a high GDP. Stockholm is a particularly extreme case comprising 41% of regional collaborations in the set, and increasing its share in Swedish GDP from 22% in 1970 to 30% in 2010.

The number of innovations produced in each region by decade and innovation agency involvement is related to log regional GDP in Figure 6. Observations from the three most populous regions are highlighted in color, while bigger nodes indicate the involvement of innovation agencies. Quadratic trend lines are fitted for innovation agency involvement separately. Overall regional collaborations are positively related to GDP, thus, they occur most frequently where economic activity is concentrated. Nonetheless, this relationship is less pronounced when innovation agencies are involved, particularly at low levels of GDP, while the relationship is stronger for regions with particularly high GDP. A common characteristics of collaborations involving innovation agencies is the fostering of connections between technical universities and local companies. These collaborations can act as a channel to transform research output into economically viable processes (Kauffeld-Monz and Fritsch, 2013). This is also a characteristic of local collaboration involving innovations agencies. While collaborations between local companies and technical universities account for only 28% of collaborations not involving innovation agencies, their share amounts to 72% of local partnerships where innovation agencies are involved. Examples include collaborations between Chalmers and Volvo (Västra Götaland); Lund

University and Alfa Laval (Skåne); Climeon, KTH and Stockholm University (Stockholm); Linköping University and Saab-Scania (Östergötland).

5.4 Other central actors

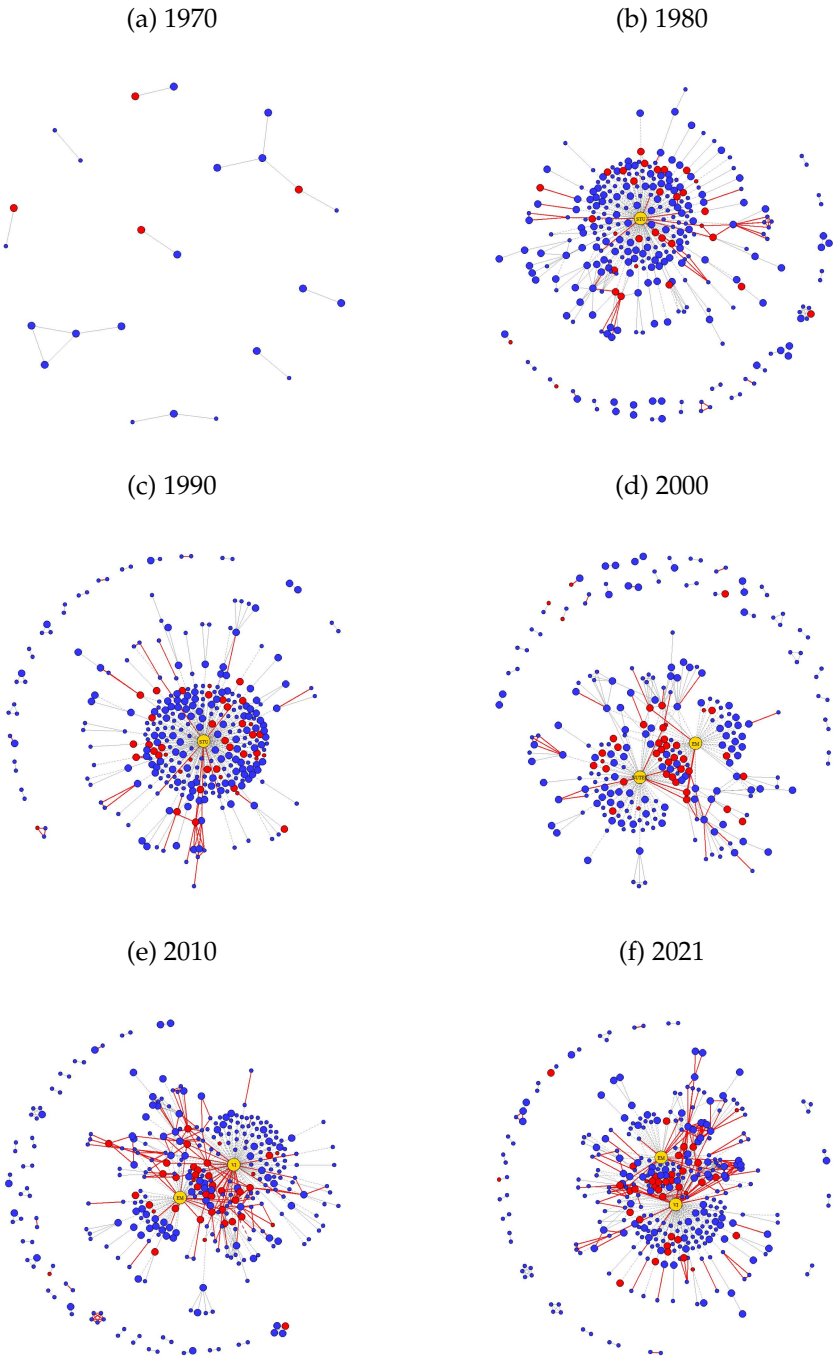
The results of this study demonstrate that innovation agencies have the greatest brokerage power in the innovation network both in term of direct contacts and betweenness. Nonetheless, they are not the only central actors in the network. Previous literature identifies universities and firms taking on the role of network brokers (Kauffeld-Monz and Fritsch, 2013; Kirkels and Duysters, 2010; Expósito-Langa et al., 2026)

For each year between 1970 and 2021, the top 10 firms in terms of degree and betweenness have been identified and ranked. After excluding the innovation agencies, 10 firms and institutions are presented in the top 10 more than 10 times over the observation period. The 10 actors included most frequently in the list are all major Swedish companies (Asea, Saab, Volvo, Ericsson), technical universities (Lund University, KTH, Chalmers, Linköping University, Luleå university), and the privately owned research group Swerea.

The central position of universities in innovation networks is line with previous findings from literature (Kauffeld-Monz and Fritsch, 2013; Kirkels and Duysters, 2010). Moreover, technical universities are the main producers of knowledge needed to development new technologies and process, and among the main targets of innovation agencies networking activity (FRN, 1986; Schilling, 2005, p. 83-84).

Further, all these firms and organizations have been in close contact with Swedish innovation agencies since the 1970s, and seven of them (Lund University, KTH, Chalmers, Linköping University, Asea, Volvo, Ericsson) are even specifically named in the examples of Weinberger (1997, p. 441-454,457-460) on the creation of framework programs. This is also visible in Figure 7, where these 10 firms and organizations are highlighted. Due to their frequent engagement in collaborative innovation and applications for public funding, they are present in the innovation network throughout the observation, and part of the central component including the innovation agency.

Figure 3: Snapshots of the Swedish innovation network, 1970–2021



Note: Publicly funded innovation are indicated by thicker red edges. Bigger nodes illustrate large firms (>200 employees), while red nodes indicate public ownership.

Figure 4: Ego-network metrics, 1972–2021 (5-year moving average)

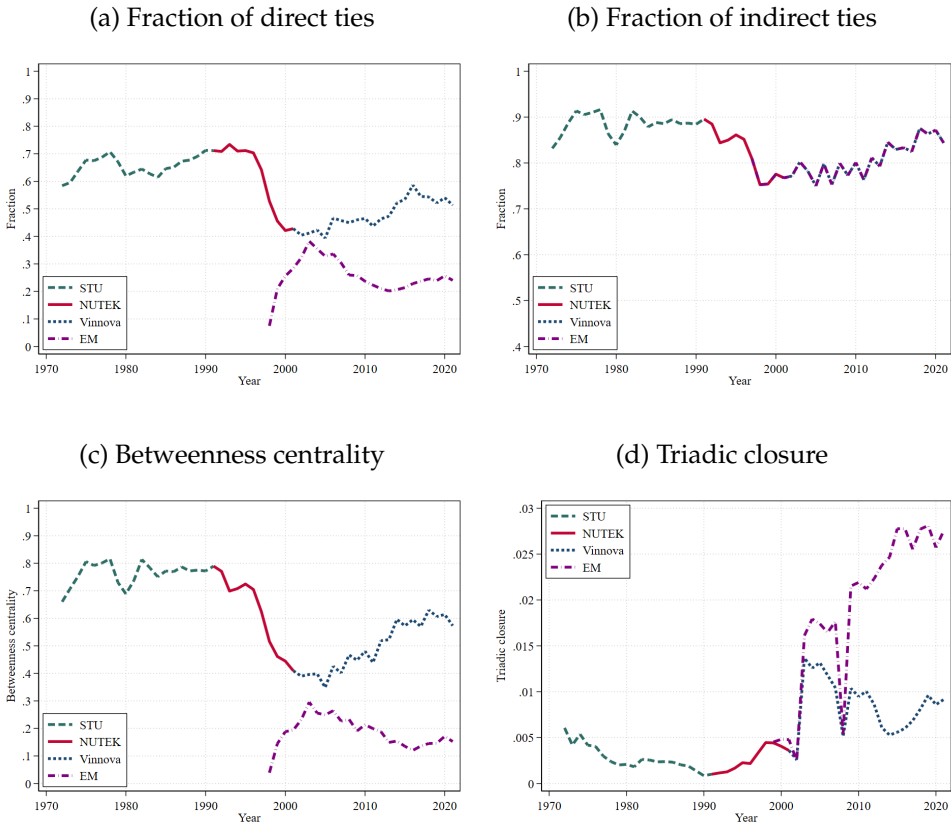


Figure 5: Links to innovation agencies, 1970–2023

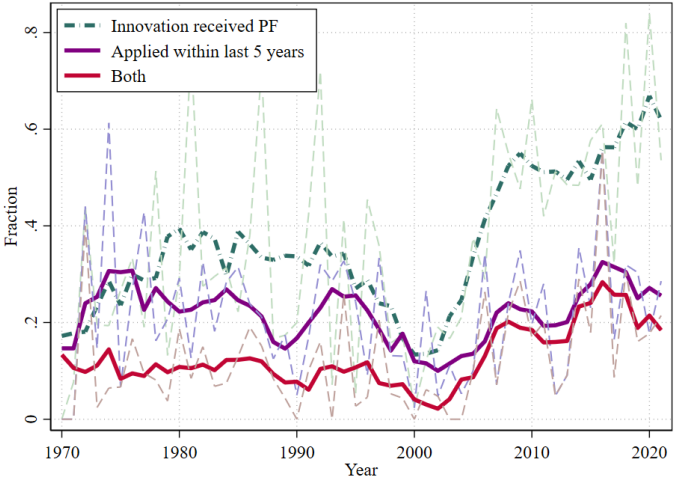
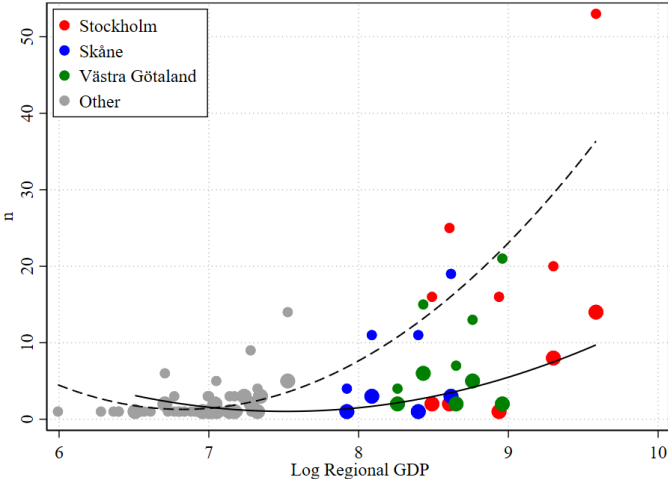


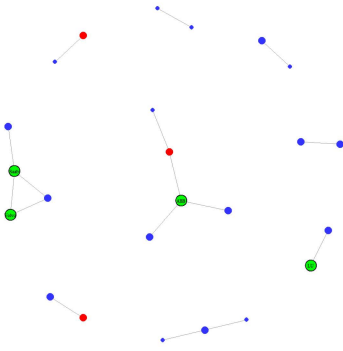
Figure 6: Local collaboration vs. Regional GDP, 1970-2021



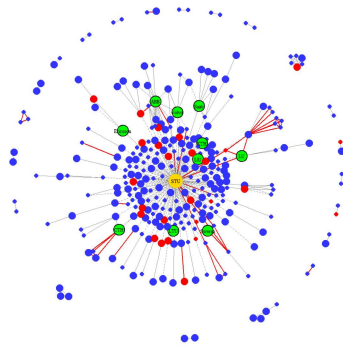
Note: The number of innovations is summarized by decade. The node for Stockholm, excluding innovation agencies during the 2010s, was dropped for illustrative purposes as it was an extreme outlier (n=48).

Figure 7: Other central actors, 1970-2021

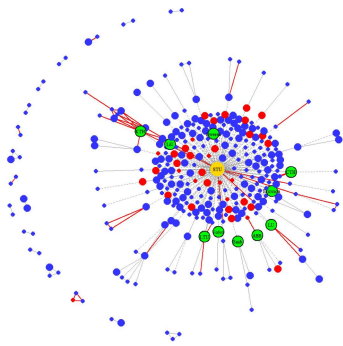
(a) 1970



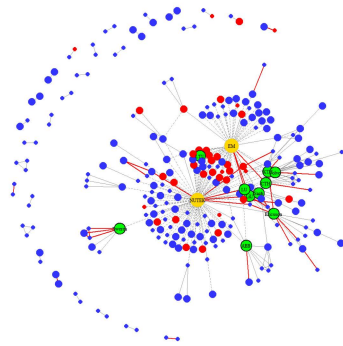
(b) 1980



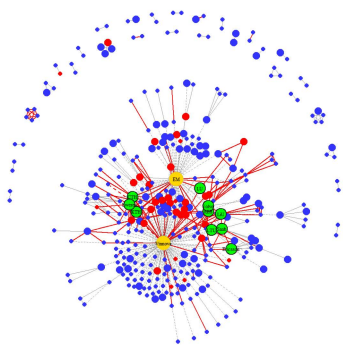
(c) 1990



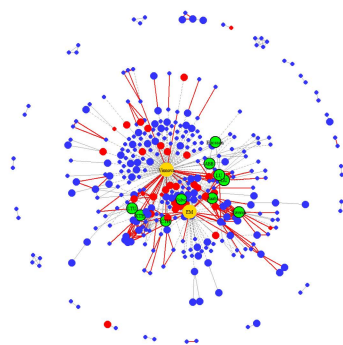
(d) 2000



(e) 2010



(f) 2021



6 Concluding remarks

This study contributes to the literature on network brokerage, by providing a case study of Swedish innovation agencies, STU, NUTEK, VINNOVA and Energimyndigheten based on innovative Swedish firms between 1970 and 2021. The study focuses on quantifying the brokerage position on innovation agency, as well as identifying changes in collaboration patterns when innovation agencies are involved. In contrast to previous studies, the study's design allows to observe dynamics in networking behavior over time and across sectors.

The Swedish innovation network is characterized by small-worldness. Thus, most nodes are not directly connected but can reach one another through the innovation agency. Swedish innovation agencies yield substantial brokerage power from a structural perspective. They are directly and indirectly connected to 40-70% and 75-90% of firms, respectively. Moreover, they are the intermediary contact for 40-80% of possible collaborators.

Further, the results of the probabilistic regression indicate that public funding ties are associated with a higher likelihood of producing collaboration between unlikely collaboration partners. While the Swedish innovation network taken as a whole displays strong signs of homogeneity in ownership, firm size, and degree centrality, the involvement of innovation agencies is correlated with collaborator pairs differing in ownership and degree centrality by 9.5% and 10.2%, respectively. In addition, the involvement of innovation agencies is positively associated with the formation of regional clusters, promoting particularly connections between technical universities and local companies. Estimation results are robust to variations in tie persistence, and the inclusion of macroeconomic controls.

Surprisingly, collaboration between firms differing in size is only significantly correlated with innovation agency involvement during the 2010s, despite efforts of policy makers to engage particularly SMEs in innovation development since the 1990s. This result might be driven by lacking or ineffective incentives to involve SMEs during until recently.

While these results alone cannot be interpreted as evidence for network additivity, it is promising since diverse sets of collaborators are identified in literature as being most likely in producing highly significant or radical innovations (Filippetti and Zinilli, 2023; Kang and Hwang, 2016; Burt, 1992).

Future research focusing on the networking behavior of STU's successors NUTEK, VINNOVA and Energimyndigheten could add a qualitative dimension to the results presented in this study. Moreover, since there are yet no comparable studies in other countries, estimating the brokerage power of other innovation agencies could provide an additional explanation for international differences in innovating behavior.

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Appendix A: Variable construction

This appendix details the construction of the main independent and control variables used in the probabilistic regression model. Firm size is a standard control in network studies (Jové-Llopis and Segarra-Blasco, 2018; Kesidou and Demirel, 2012; Bronzini and Piselli, 2016; Hottenrott and Lopes-Bento, 2014), and crucial in the Swedish case since firm size determines to what extent public funding bodies are allowed to support R&D costs since the 1990s (Energimyndigheten, 2019; Vinnova, 2021). This paper distinguishes between small, medium, and large firms, as firms with between 0 and 49 employees, between 50 and 199 employees and 200 employees or more, respectively.

For the main innovating firms, SWINNO has been linked to employment data from the SCB (2023) until 2013 and the Serrano database from 2014 onwards (Kreutzer and Taalbi, 2026). The Serrano database contains information on firm size, location, and revenue of Swedish firms from 1997 onwards, providing information on firm size of 597 main innovative firms (Weidenman, 2025). This information has been complemented in this study by linking Serrano to collaborating firms from 1997 onwards. In this way information on firms size has been obtained for 177 additional firms.

Universities, public authorities, and hospitals were classified as large if observations on firm size were missing, creating observations for 52 additional firms. Thereafter information on firm size was still missing primarily for foreign firms since they were only in rare cases reported in Swedish registry data. Thus, a manual internet search was conducted, searching company websites and online registries were consulted to obtain approximate employee counts. In total, 450 observations on firm size were created this way, including 75% of employee counts of foreign companies.

Table 8: Size of innovative firms

Size	Freq.	Percent
Small (<50)	756	54.39
Medium (50–200)	105	7.56
Large (>200)	403	28.99
Missing	126	9.06
Total	1,390	100.00

As presented in Table 8, the distribution of firm size is heavily U-shaped, consisting primarily of small and very large firms. More than half of the innovative firms in the data set are classified as small, while large and medium sized firms

make up 29% and 7.5%, respectively. In case that information on firm size is missing firms are declared to be small since they are the biggest group among the innovative firms. Alternative regression results considering only observations on firm size originating from SWINNO and Serrano are provided in the appendix.

Information on public ownership is primarily sourced from SWINNO, and complemented with information from the Public Funding Database. In case information was missing universities, and public authorities have been classified as publicly owned. In total 98 firms have been declared to be under public ownership corresponding to 7% of firms in the dataset.

While the location variable is available on the city level for most main innovating firms, the location of collaborators is merely provided on the national level. Since this study investigates among other whether public funding promotes the emergence of local cluster this is particularly an issue for Swedish firms.

SWINNO contains information on the exact location for 631 Swedish firms and countries for foreign firms. This information was complemented with information on the location obtained from firm names, and the Serrano database, adding 106 additional observations. The location of 574 firms was determined based on a manual internet search, based on information from online company registers, company websites, and Wikipedia in case of dissolved companies and organizations. Only in 81 cases the location of innovative firms could not be determined. Similar as in the case of firm size, alternative regressions are included that only includes observation if firm size data is sourced from SWINNO or Serrano.

The location of firms by regions is presented in Table 9. The top three Swedish locations are Stockholm, Västra Götaland, and Skåne, coinciding with the location of Sweden's most populous cities. 22% of firms in the dataset are located in Stockholm alone. 14% of firms in the dataset are of foreign origin. Swedish firms collaborate most frequently with firms based in the US, Germany, and other Scandinavian countries.

Firm degree is calculated based on the edge list for each single year, calculating the number of collaborations and public funding edges that each firm is part of. To avoid including bad control variables, the degree variable included in the regression refers to the previous year.

As presented in Table 10, the degree variable, varies between values of 0 and 27. Values of zero indicate that the firm has neither applied for public funding nor developed an innovation for the past 5 years. Bins are created capturing degrees from 0–4, 5–9, etc. Thus, a match in degree is no exact match but rather an indication of highly and less connected firms.

Table 9: Location of innovative firms

Län	Freq.	Percent
Blekinge	18	1.38
Dalarna	29	2.22
Gotland	1	0.08
Gävleborg	32	2.45
Halland	32	2.45
Jämtland	3	0.23
Jönköping	49	3.75
Kalmar	20	1.53
Kronoberg	17	1.30
Norrbottn	38	2.91
Skåne	150	11.48
Stockholm	288	22.04
Södermanland	20	1.53
Uppsala	34	2.60
Värmland	25	1.91
Västerbotten	37	2.83
Västernorrland	28	2.14
Västmanland	26	1.99
Västra Götaland	186	14.23
Örebro län	23	1.76
Östergötland	69	5.28
Foreign	182	13.93
Unknown	81	5.83
Total	1,390	100.00

Table 10: Degree of innovative firms, 1970–2021

Degree	Freq.	Percent	Cum.
0	1,864	90.66	90.66
1	24	1.17	91.83
2	16	0.78	92.61
3	18	0.88	93.48
4	17	0.83	94.31
5	10	0.49	94.80
6	12	0.58	95.38
7	16	0.78	96.16
8	20	0.97	97.13
9	10	0.49	97.62
10	13	0.63	98.25
11	7	0.34	98.59
12	4	0.19	98.78
13	4	0.19	98.98
14	8	0.39	99.37
15	1	0.05	99.42
16	4	0.19	99.61
17	1	0.05	99.66
18	1	0.05	99.71
20	1	0.05	99.76
21	3	0.15	99.90
27	2	0.10	100.00
Total	2,056	100.00	

Appendix B: Sensitivity Analysis

Alternative definitions of tie persistence

One of the strongest assumption in this study is that ties between innovation agencies and applicants, as well as among collaborators persist for five years. This affects both the estimation of brokerage power, and the construction of the variable degree centrality. This section presents results for brokerage power of innovation agencies, as well as of differences between collaboration involving and not-involving innovation agencies, with varying tie persistence. Persistence is varied between 1 and 10 years.

Snapshots of the 1980 and 2015 networks are presented in Figure 8, for ties persisting for 1, 5, and 10 years separately. Network size increases substantially with tie persistence. For a persistence of one year it varies between 77 and 170, compared to 114 and 556 when ties persist for a decade. Correspondingly, the innovation agencies number of direct ties increases from a maximum of 148 to 300.

Nonetheless, the brokerage position of innovation agencies is barely affected by variation in tie persistence. The brokerage position is assessed in this study based on the innovation agencies betweenness and degree centrality, which are presented for alternative persistence in Figure 9. Both degree and betweenness centrality are generally slightly higher when tie persistence increases but never vary by more than a factor of 0.7 and 0.67, respectively.

This can most likely be accounted to the way in which these measures are calculated. Since both measures are normalized, their values are inversely related with network size. Betweenness centrality refers to the fraction of cases when innovation agencies are located on the shortest paths between two nodes in the network.⁹ Degree centrality is the number of direct ties of the innovation agency divided by the number of possible connections to other ties.¹⁰

While brokerage power is only affected by a limited extent, the number of collaborations involving innovation agencies rises from 166 to 353, when tie persistence increases from 1 to 10 years. The fraction of collaborations involving innovation agencies is sensitive to variations in tie persistence particularly during the 1980s and 2010s (see Figure 10). This could potentially have significant effect on the results of the probabilistic regression since more than twice as many and potentially systematically different collaborations classify as being facilitated by innovation agencies.

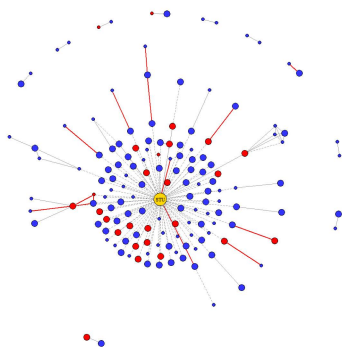
Regression results with varying tie persistence are presented in Table 11. As in Table 12, results are presented for the most conservative definition of innovation

⁹Betweenness centrality: $C_B(i) = \frac{2}{(n-1)(n-2)} \sum \frac{\sigma_{st}(i)}{\sigma_{st}}$

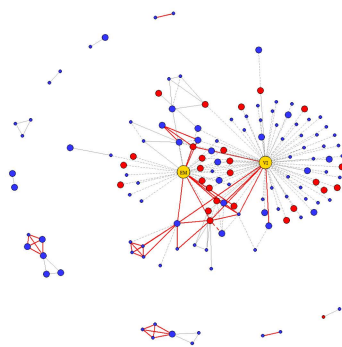
¹⁰Degree centrality: $C_D(i) = \frac{k_i}{n-1}$

Figure 8: Alternative tie persistence, 1980, 2015

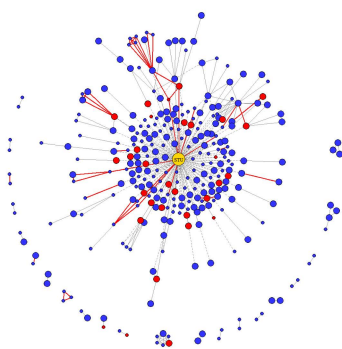
(a) 1980 – 1 year



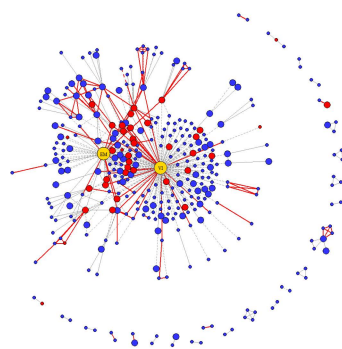
(b) 2015 – 1 year



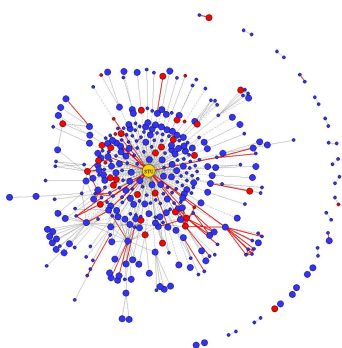
(c) 1980 – 5 years



(d) 2015 – 5 years



(e) 1980 – 10 years



(f) 2015 – 10 years

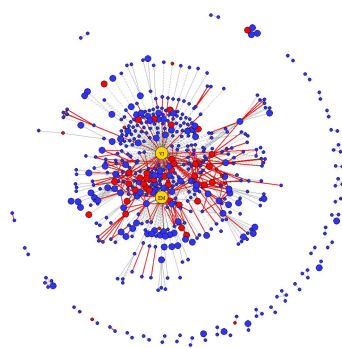


Figure 9: Ego-network metrics – Alternative persistence, 1972–2021

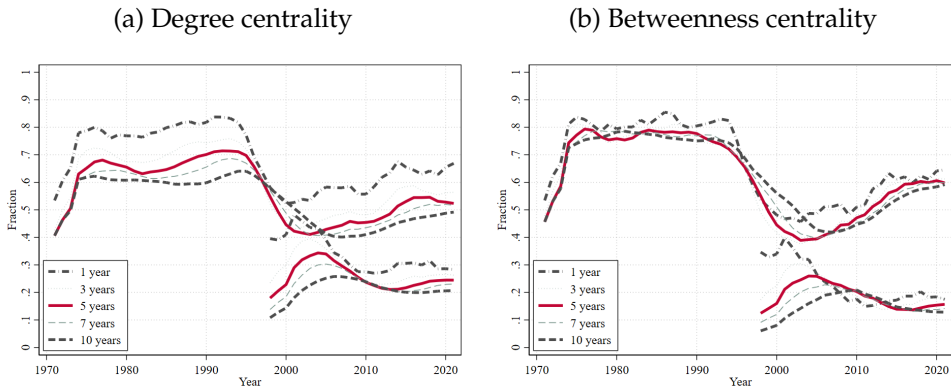
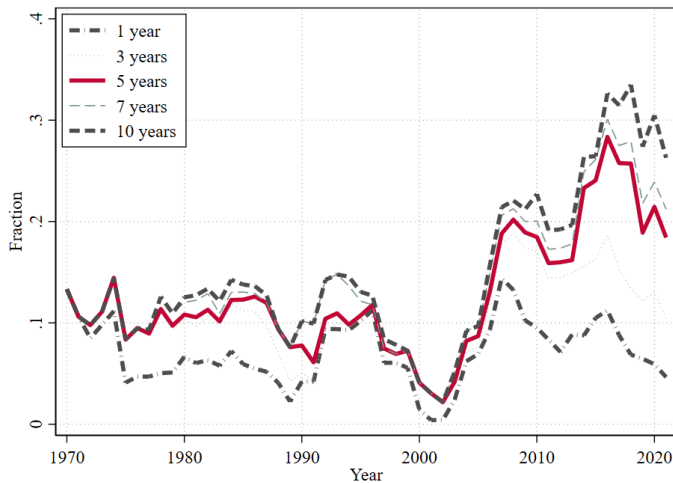


Figure 10: Collaborations linked to innovation agencies – alternative tie persistence, 1970–2021



agency involvement, recent contact of both collaboration partners with the innovation agency and receiving public funding for the development of the innovation in question. Moreover, the degree variable has been adjusted to account for variations in tie persistence.

While coefficients vary with tie persistence, the direction of coefficients is consistent across model specifications. Moreover, apart from firm size, which lacks significance independent of the level of tie persistence, all estimated effects are significant at the 0.1% level. Generally the size of the marginal effects increases

Table 11: Differences in collaborator characteristics – alternative tie persistence

	1 year		3 years		5 years		7 years		10 years	
	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.
Match firm size	0.101 (0.371)	0.011 (0.372)	0.015 (0.871)	0.002 (0.871)	-0.010 (0.907)	-0.002 (0.907)	0.019 (0.832)	0.003 (0.832)	0.010 (0.903)	0.002 (0.903)
Match location	0.167 (0.166)	0.018 (0.166)	0.124 (0.228)	0.018 (0.228)	0.144 (0.137)	0.024 (0.136)	0.097 (0.303)	0.017 (0.303)	0.094 (0.301)	0.018 (0.300)
Match ownership	-0.682*** (0.000)	-0.073*** (0.000)	-0.678*** (0.000)	-0.099*** (0.000)	-0.604*** (0.000)	-0.100*** (0.000)	-0.592*** (0.000)	-0.106*** (0.000)	-0.602*** (0.000)	-0.117*** (0.000)
Match degree	-0.425*** (0.002)	-0.045*** (0.002)	-0.543*** (0.000)	-0.080*** (0.000)	-0.457*** (0.000)	-0.076*** (0.000)	-0.433*** (0.000)	-0.078*** (0.000)	-0.311*** (0.000)	-0.061*** (0.000)
Constant	-2.349*** (0.000)		-1.684*** (0.000)		-1.593*** (0.000)		-1.537*** (0.000)		-1.573*** (0.000)	
Observations	1921	1921	2027	2027	2027	2027	2027	2027	2027	2027
Pseudo R-sq	0.257		0.227		0.214		0.209		0.198	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inno. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Notes:

*p<0.05; **p<0.01; ***p<0.001

with rising tie persistence. The fit of the regression model is slightly better with lower tie persistence. Nonetheless, all pseudo R^2 values, except for the 2010s, exceed the value of 0.2 indicating a good fit of the model (Hemmert et al., 2018). To summarize, varying tie persistence has primarily an effect on illustration of the innovation network, and the size of the coefficients in the probabilistic regression model. However, since metrics for assessing brokerage power and the direction of the correlations in collaborator characteristics are consistent, the results of the presented analysis are deemed as robust to variations in tie persistence.

Variation over time

As the second part of the analysis utilizes a regression model to estimate collaborator patterns, variations over the observation period are not easily discernible. For this reason, Table 12 presents the regression results split by decade. It should be noted that in this case only results for the third definition of innovation agency involvement are displayed. Overall, this way less significant estimates are produced, since the number of observations drops to merely 196–626 observation per decade.

The results in Table 12 reveal that the significance of correlations between innovation agency involvement and main independent variables drops substantially when splitting the regression by decade. Particularly for the 1970s and 1990s with merely 196 and 241 observations estimates lose significance. Nonetheless, the direction of ownership, degree, and location is consistent.

The fit of the regression model improves when the regression is broken down by decade. Apart from the 1980s and 2010s, the pseudo R^2 exceeds 0.2 which is

Table 12: Differences in collaborator characteristics – Divided by decade

	1970s		1980s		1990s		2000s		2010s	
	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.
Match firm size	0.004 (0.991)	0.001 (0.991)	-0.185 (0.386)	-0.028 (0.386)	-0.122 (0.667)	-0.017 (0.666)	0.185 (0.367)	0.031 (0.366)	-0.233* (0.095)	-0.049* (0.094)
Match location	0.500 (0.208)	0.069 (0.204)	0.502** (0.024)	0.075** (0.023)	0.306 (0.384)	0.043 (0.383)	0.122 (0.606)	0.021 (0.606)	0.149 (0.321)	0.032 (0.319)
Match ownership	-0.592 (0.109)	-0.082 (0.106)	-0.640*** (0.007)	-0.096*** (0.007)	-0.042 (0.894)	-0.006 (0.894)	-0.970*** (0.000)	-0.163*** (0.000)	-0.611*** (0.000)	-0.129*** (0.000)
Match degree	-1.306*** (0.004)	-0.181*** (0.003)	-0.438 (0.116)	-0.065 (0.116)	-0.251 (0.578)	-0.035 (0.577)	-0.789** (0.022)	-0.133** (0.020)	-0.624*** (0.004)	-0.132*** (0.003)
Constant	0.039 (0.957)		-0.135 (0.796)		-1.894** (0.011)		0.174 (0.769)		-0.262 (0.634)	
Observations	196	196	406	406	241	241	360	360	626	626
Pseudo R-sq	0.328		0.173		0.252		0.301		0.164	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inno. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Notes:

*p<0.05; **p<0.01; ***p<0.001

considered to be an good fit in social science literature (Hemmert et al., 2018). For the 1970s it is with 0.328 approaching the classification of an excellent fit. Overall the estimated correlations for ownership and degree are most similar to the main regression results and significant for 3 out of 5 decades each. Creating local partnerships was significantly correlated with the involvement of innovation agencies only during the 1980s. The marginal effect amounts to 7.5%. The temporal division of the regression results reveals that innovation agency involvement is significantly correlated with collaboration among firms differing in size during the 2010s. This points to an improvement in incentives to promote collaborations between firms of different sizes over recent years.

Further, the observation period has been split by the incumbency of the main innovating agencies STU (1970–1991), NUTEK (1991–2001), and VINNOVA (2001–present). The results are presented in Table 13. The estimation results for STU and NUTEK are similar to Table 6, with an exception of the estimate for location being insignificant during the VINNOVA period. Moreover, estimates for the NUTEK period are insignificant, similar to the estimates for the 1990s in Table 12. This can most likely be accounted to the small number of observations during the period.

Macroeconomic condition

To control for changes in macroeconomic conditions, controls for GDP growth are included in the probabilistic regression model. Data on GDP growth is obtained from the Swedish Historical National Accounts (Schön and Krantz, 2012). Like degree controls these refer to the previous year to prevent the inclusion of bad controls and since budgets and funding targets for innovation

Table 13: Differences between collaborator characteristics – Divided by agency

	STU		NUTEK		VINNOVA	
	Probit	Marg. effect	Probit	Marg. effect	Probit	Marg. effect
Match firm size	-0.123 (0.462)	-0.017 (0.462)	-0.084 (0.759)	-0.012 (0.759)	-0.098 (0.384)	-0.020 (0.383)
Match location	0.495*** (0.006)	0.067*** (0.006)	0.354 (0.300)	0.049 (0.299)	0.161 (0.193)	0.032 (0.192)
Match ownership	-0.516*** (0.005)	-0.070*** (0.005)	-0.044 (0.888)	-0.006 (0.888)	-0.672*** (0.000)	-0.133*** (0.000)
Match degree	-0.662*** (0.002)	-0.090*** (0.002)	-0.550 (0.185)	-0.076 (0.180)	-0.641*** (0.000)	-0.127*** (0.000)
Constant	-0.412 (0.357)		-1.621** (0.022)		-0.979** (0.024)	
Observations	703	703	256	256	994	994
Pseudo R-sq	0.193		0.240		0.197	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Innovation controls	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No

agencies are determined one year in advance.

Table 14: Differences in collaborator characteristics including macro control

	Funded innovation		Funding applicants		Both	
	Probit	Marg. effect	Probit	Marg. effect	Probit	Marg. effect
Match firm size	0.017 (0.797)	0.005 (0.797)	-0.031 (0.672)	-0.007 (0.672)	-0.125 (0.147)	-0.021 (0.146)
Match location	0.066 (0.400)	0.021 (0.400)	0.252*** (0.003)	0.060*** (0.003)	0.219** (0.024)	0.036** (0.024)
Match ownership	-0.295*** (0.000)	-0.094*** (0.000)	-0.595*** (0.000)	-0.140*** (0.000)	-0.577*** (0.000)	-0.095*** (0.000)
Match degree	-0.342*** (0.003)	-0.110*** (0.003)	-0.600*** (0.000)	-0.142*** (0.000)	-0.623*** (0.000)	-0.102*** (0.000)
GDP growth	0.006 (0.606)	0.002 (0.606)	-0.010 (0.455)	-0.002 (0.455)	-0.005 (0.728)	-0.001 (0.728)
Constant	-1.050*** (0.000)		-0.400 (0.125)		-1.219*** (0.000)	
Observations	2033	2033	2033	2033	2027	2027
Pseudo R-sq	0.164		0.142		0.204	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Innovation controls	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No

Notes:

*p<0.05; **p<0.01; ***p<0.001

The results including controls for GDP growth are presented in Table 14. While GDP growth is significant for the different aspects of innovation agency in-

volvement, it loses significance in column (3). Otherwise neither the direction, estimation precision, nor magnitude are significantly affected by the inclusion of macroeconomic conditions.

Table 15: Differences in collaborator characteristics including macro control – Divided by decade

	1970s		1980s		1990s		2000s		2010s	
	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.	Probit	Marg. eff.
Match firm size	0.058 (0.866)	0.008 (0.866)	-0.193 (0.367)	-0.029 (0.367)	-0.165 (0.568)	-0.023 (0.566)	0.183 (0.374)	0.031 (0.373)	-0.239* (0.090)	-0.050* (0.088)
Match location	0.538 (0.192)	0.071 (0.187)	0.517** (0.020)	0.077** (0.020)	0.335 (0.351)	0.046 (0.350)	0.118 (0.621)	0.020 (0.621)	0.082 (0.594)	0.017 (0.594)
Match ownership	-0.640* (0.089)	-0.085* (0.085)	-0.634*** (0.007)	-0.094*** (0.008)	-0.024 (0.940)	-0.003 (0.940)	-0.969*** (0.000)	-0.163*** (0.000)	-0.637*** (0.000)	-0.133*** (0.000)
Match degree	-1.246*** (0.006)	-0.165*** (0.005)	-0.476* (0.094)	-0.071* (0.093)	-0.397 (0.393)	-0.054 (0.393)	-0.787** (0.023)	-0.132** (0.020)	-0.609*** (0.004)	-0.127*** (0.004)
GDP growth	-0.099* (0.078)	-0.013* (0.072)	-0.061 (0.362)	-0.009 (0.362)	-0.101* (0.087)	-0.014* (0.083)	0.002 (0.918)	0.000 (0.918)	0.103** (0.016)	0.021** (0.015)
Constant	0.158 (0.828)		0.025 (0.965)		-1.747** (0.023)		0.182 (0.760)		-0.460 (0.422)	
Observations	196	196	406	406	241	241	360	360	626	626
Pseudo R-sq	0.351		0.177		0.270		0.301		0.174	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inno. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Notes:

*p<0.05; **p<0.01; ***p<0.001

Also when splitting regression results by decade no major changes in the direction and magnitude of estimates can be observed (see Table 15). Merely innovation precision and the model fit are slightly improved.

Firm size and Location

As discussed in the data section, exact employment and location data has only been collected for main innovating firms in SWINNO. This leaves more than half of innovating firms with incomplete information on the number of employees, which has been filled in by individual work. To check whether this limit in data availability biases the estimation results, regression results for collaborations where firm size and location information is available for both collaborators are included in Table 16. Columns represent regression results with information pn

The exclusion of observations where confirmed information on firm size information is not available for both collaboration partners drastically reduces the number of observations to merely 50% of the original sample. When the sample is restricted to collaborations where information on firm size and location is available for both partners none of the correlations is significant. When ensuring that observations on firm size and location are available for both partners separately, the estimated effects are in line with the baseline results. The only

Table 16: Differences in collaborator characteristics – only confirmed firm size and location

	Firm size		Location		Both		Baseline	
	Probit	Marg. effect	Probit	Marg. effect	Probit	Marg. effect	Probit	Marg. effect
Match firm size	0.037 (0.782)	0.007 (0.782)	-0.162 (0.296)	-0.037 (0.295)	0.028 (0.882)	0.008 (0.882)	-0.014 (0.867)	-0.002 (0.867)
Match location	0.357** (0.027)	0.071** (0.026)	0.503*** (0.006)	0.114*** (0.006)	0.124 (0.594)	0.033 (0.593)	0.238** (0.014)	0.039** (0.013)
Match ownership	-0.337* (0.076)	-0.067* (0.076)	-0.408** (0.018)	-0.093** (0.017)	-0.260 (0.313)	-0.069 (0.312)	-0.589*** (0.000)	-0.097*** (0.000)
Match degree	-0.594*** (0.001)	-0.118*** (0.001)	-0.469* (0.051)	-0.106** (0.049)	-0.324 (0.230)	-0.086 (0.228)	-0.661*** (0.000)	-0.109*** (0.000)
Constant	-0.844** (0.037)		-0.847* (0.066)		-0.817 (0.129)		-0.922*** (0.002)	
Observations	742	742	544	544	332	332	2027	2027
Pseudo R-sq	0.111		0.139		0.089		0.207	
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Innovation controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	No	Yes	No	Yes	No	Yes	No

Notes:

* p<0.05; ** p<0.01; *** p<0.001

exception from this is the correlation between public funding and location, whose amplitude increases by a factor of 3, suggesting that public funding is associated with a 11.4% higher probability of promoting regional partnerships.

Paper IV



The effect of public funding on Swedish innovation, 1970-2001*

Johanna Fink[†] and Sara Torregrosa-Hetland[‡]

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Abstract

This paper analyses the effects of innovation policy on innovation output. We use a database of Swedish innovations (1970-2001), linked to both approved and non-approved public funding projects, and combine logistic regressions with matching approaches. We address: (1) the characteristics of firms applying for public funding, (2) the effects of public funding on the generation of significant innovations, and (3) whether granting more funding to a project impacts on the importance of the innovation. We find evidence of strong output additionality, as approved public funding projects were twice as likely than non-approved ones to translate into significant innovations. Moreover, our results indicate that firms were more likely to apply for public funding when they had already obtained it previously, were publicly owned, small, and located in major cities. Innovations that applied for greater amounts of public funding were of higher significance. Output additionality was strongest during the 1980s, pointing towards greater importance of public funding when private funding availability is limited, as venture capital became only widely available from the 1990s onwards. This aligns with the finding that output additionality was highest among small firms, whose access to alternative innovation finance is limited.

Keywords: innovation, LBIO, public funding, public policy.

JEL codes: O38, N44, N74

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1 Introduction

Innovation policy in most Western countries is to a large extent geared towards public support of innovation activities conducted by firms. The justification of such government intervention is rooted in neoclassical economic theory, positing that governments should intervene in economic activity in the presence of market failure. Since individual firms do not take into account externalities when making their investment decisions, governments should actively foster innovation to reach socially optimal levels of R&D activity (Nelson, 1959; Arrow, 1962). More recent work has underlined the importance of government initiatives in innovation, not only as a complement but as a central actor for important breakthroughs, for example in the United States during the postwar era (Mazzucato, 2013).

Public innovation funding, like all use of public money, should be scrutinized. The concept of additionality is crucial in such evaluation: good public policy should entail a positive change in some outcome that we are interested in. If this change is not found (i.e., if there is no additionality), we may conclude that the policy was not effective and that public resources might have been put to better use elsewhere.

In the innovation literature, additionality has been approached in different ways, by looking at inputs, outputs, or behaviors in the innovation process (Falk, 2007). For inputs, the usual question has been whether public funds crowd out, complement, or even foster private R&D spending. Behavioral additionality has dealt with how firms innovate. This paper is located in the second stream of this literature, focusing on the outputs or results of the innovation process. We ask whether we can detect additionality in the public funding of Swedish innovation projects between 1970 and 2001, in the sense of actual new products introduced in the market and how significant they were.¹

Three questions are addressed in the paper: (1) What innovative firms apply for public funding? (2) Are approved public funding projects more likely to translate into significant innovations? (3) How is getting more funding translated into innovation significance? To approach these questions, we combine logistic regressions with three alternative matching approaches (propensity score matching, nearest neighbor matching and inverse probability weighting). The main contribution of the paper is the combination of a robust control group with the use of innovations themselves as an output indicator. We construct our

¹Our definition of innovation follows the Oslo Manual (2005, p.46): "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". However, because of data availability, our focus is on products and not processes.

control group from a pool of rejected public funding applicants, thus addressing the self-selection of firms into applying for public funding. Although similar approaches have been used in some recent studies, they are still rather rare and recognized as an area of needed improvement in the literature.² We link the project applications with a database of Swedish innovations that gathers the most significant new products introduced in the Swedish economy since 1970 (Sjöö et al., 2014; Kander et al., 2019). Our data covers three decades and thus allows us to look at long-term effects and variation over time.

Sweden ranks among the most innovative countries today (Dutta et al., 2023; EU, 2023), and was among the first to establish a second generation innovation agency, aiming at promoting applied research (Weinberger, 1997; Arnold and Barker, 2022). Since the establishment of the first Swedish innovation agency in 1968, several important reconfigurations took place. This entails the creation of different innovation agencies, changes in decision-making processes, and granted funding. All these changes increase the complexity but also enrich our analysis.

The rest of the paper consists of a review of previous literature (section 2), a description of the Swedish system for public innovation funding (section 3), a presentation of our data (section 4) and methods (section 5), followed by the discussion of the results (section 6). We perform several robustness checks in section C and close in section 7.

2 Literature review

Studies on innovation policy have given great importance to the issue of additionality, but have not always been able to approach it with robust methods and sufficient data. Our paper is part of a recent strand of the literature that aims to econometrically identify additionality. We will here summarize the evolution of the literature in terms of methods and results.

The innovation outcome that we are interested in can be conceptualized in different ways. According to Falk (2007), we may consider three main areas: *input additionality* (e.g. how firms invest private funds), *output additionality* (firms' innovation performance), and *behavioral additionality* (on the process: how do the firms innovate). Out of the three, input additionality has been the object of the most well-developed literature, with origins in the 1980s, trying to measure the possible crowding-out effects of public funds on private

²Take, for example, Czarnitzki and Hussinger (2018, p. 1337): "Finally, it would be great to also have information about rejected grant applications to further improve our analysis. We share with the vast majority of previous studies on R&D subsidies that this information is not available."

R&D investments. In the words of Zúñiga-Vicente et al. (2014, p.37), “the major research question has been whether public R&D subsidies are either complementary and, thus, ‘additional’ to company-financed R&D or whether they substitute for and, thus, ‘crowd out’ private R&D” (see also David et al., 2000).

Several studies conducted in the last two decades have found no *crowding-out* effects, and actually *crowding-in* in some contexts. The latter refers to cases in which public funding triggered additional private funding; see, for example, Görg and Strobl (2007); González and Pazó (2008); Aerts and Schmidt (2008); Hussinger (2008) or Bloch and Graversen (2012). However, other studies show the opposite: no additionality or even substitution between both types of funding (for example, Marino et al., 2016 on the French system of tax credits). Lee (2011), in a study using firm-level data for six countries in Asia and North America, showed that public funding could be both complementary and substitute to private funding, depending on factors such as the technological level of the firm. The survey by Zúñiga-Vicente et al. (2014) reports that approximately 60% of the reviewed studies indicated additionality, but a substantial diversity of results is highlighted. This diversity cannot be traced back just to methodological issues, but might be better explained by the variation in aspects like the constraints faced by firms, the amount of public subsidies, etc.

Less work seems to have been done until recently on understanding behavioral additionality (OECD, 2006). Examples of firm behavior include, whether they conduct collaborative innovation, or with which priorities they innovate. According to Malik et al. (2005), behavioral additionality might take place even if neither input nor output additionality can be found. Some examples of this literature are Clarysse et al. (2009), who point toward organizational learning in Flemish firms (2001-2004), Bergman et al. (2010), who look at scale and acceleration effects in small and medium-sized Swedish firms (2002-2008), or Berrutti and Bianchi (2020), who find some improvements in organization in Uruguayan firms (2001-2015).

Our paper deals with output additionality, which is why we concentrate on this strand of the literature for the remainder of the section. We also focus on quantitative studies and not on studies with qualitative approaches. Output additionality can be of many kinds, depending on the actual output considered (Falk, 2007). The literature has quite extensively analyzed effects on firms (for example, on sales or profits). Patents have also been used as an indicator of innovation output. We will review the studies based on the dependent variable they used.

Some of the first quantitative studies about the effects of innovation subsidies on firms were conducted to evaluate the SBIR (*Small Business Innovation Research*) program in the United States. Wallsten (2000) found no effects of the program

on employment, while Lerner (1999) did. Both studies have significant methodological differences. Wallsten (2000) discusses that the absence of positive effects was the result of the program financing firms who would have been successful *also* in the absence of the public support they received, which he could capture by using an instrumental variable approach. On the other hand, Lerner (1999) argues that the positive effects he does find on both revenue and employment can be partly derived from the longer time horizon considered (ten years instead of at most three). Lerner (1999) compared the results of firms receiving public funds with those who did not (not accounting for whether they actually had applied). He attributed the positive results mostly to signaling effects: publicly funded firms attracted more private capital in the future. This argument, related to input additionality, has also been put forward in other contexts, e.g. Belgium (Meuleman and De Maeseneire, 2012), Sweden (Söderblom et al., 2015), and China (Wu, 2017).

A more recent study on the SBIR program shows positive effects on the publicly funded firms: they were more likely to get subsequent venture capital and to patent, and they generated higher revenue. The author in this case argues that the effect is not only about signaling (a kind of “seal of approval” from the public institutions), but also about the actual funding: “the grants are useful because they fund technology prototyping” (Howell, 2017, p. 1136).

Several studies of this kind have also been conducted in Sweden. Bager-Sjögren and Löf (2005) analyzed data from the public agency NUTEK, considering applications made between 1994 and 1997. They compared the firm outcomes until 2003 of a group which received public support to those of a control group based on age and sector. Their results showed positive effects on firm assets, sales, employment, and labor productivity – but only on new and independent firms. Johnson et al. (2008) focused on new firms receiving public seed finance, following and further developing the previous study. They considered the 1994 applicants using data until 2006, and constructed the control group using also information on firm size, finding positive effects on revenue and employment. One problem with these studies is that they did not take into account selection into applying for a public funding innovation program. Firms who apply can be thought as being different from firms who do not, as they at least have an innovation idea. Therefore, when not controlling for this and simply comparing their outcomes to those of other firms in the country, the results might be partially driven by selection bias (see the discussion in Cerulli, 2010).

Even if it is a more dated article, Klette et al. (2000) remains interesting because it pays particular attention to conceptual aspects. They review several econometric studies on both input and output additionality, discussing the challenges in obtaining a valid control group. As will be shown in this paper as well, neither firms applying for public funding nor those receiving it are random. This leads

to thinking about the interpretation of the results of the studies, in the presence of potential selection bias. They also focus on the existence of spillovers, which may lead to underestimating the effects of public R&D support programs, but which are often an important justification for these.

In order to tackle this issue, Norrman and Bager-Sjögren (2010) used a different control group in their evaluation of the Swedish Innovation Center, which was active between 1994 and 2003. The control group was built by matching the supported firms with non-supported ones who had applied for public funding but were rejected, on the basis of a set of variables.³ Their conclusion was that positive impacts of the SIC support on their outcome variables (sales, assets, employment) were “weak or non-existent” (Norrman and Bager-Sjögren, 2010, p. 615). The authors suggest, however, that a longer time frame might be needed to fully capture any effects.

A couple of recent papers have looked at other Swedish innovation programs from the early 21st century. Daunfeldt et al. (2016) study *Forska & Våx* and *Vinn Nu* in the period 2002-2010. They generate a control group by coarsened exact matching and estimate a diff-in-diff model to evaluate the effects of the program on the economic performance of firms. This study did not find any effects on the considered variables (number of employees, labor productivity, revenue growth, and researchers in staff). On the other hand, Söderblom et al. (2015) studied the *Vinn Nu* program, considering applications from 2002-08, and with data until 2011. Their method is an OLS regression with a control group built out of firms who were rejected *at the last stage* of the selection process. They find positive effects on firm performance in terms of sales and employment, which are not driven by the subsidy itself but by the fact that firms funded by the program also get access to more human and financial capital. This is closely connected to the signaling effect mentioned above.

As advanced earlier, other studies have considered patents as the output of interest. This literature has normally found positive effects, in the sense that firms with access to public funding were more likely to file patents. This is the case, for example, of Czarnitzki and Licht (2006) in a study about Germany in the 1990s, Plank and Dobliger (2018) with respect to the German renewable energy sector (2006-2015), or Widmann (2024) on Austria in the early 2000s. Czarnitzki et al. (2007) compared Finland to Western Germany in the late 1990s, finding stronger effects in the first.⁴

Finally, what about looking at innovations themselves, the actual new products introduced? Our paper is part of a still scarce but developing literature that

³A precedent to this approach can be found in Brown et al. (1995), who evaluated a US Department of Energy program based on such a control group of rejected applicants.

⁴Both Czarnitzki and Licht (2006) and Czarnitzki et al. (2007) also look at input additionality in terms of firms’ R&D expenditures.

aims to explore output additionality with this angle. Hewitt-Dundas and Roper (2010) found positive effects of public support in the share of sales corresponding to new products, in a study on manufacturing firms in Ireland and Northern Ireland (1994-2004). A similar approach and results are found in Prencipe et al. (2024), who studied Spanish firms in 2009-14. Bérubé and Mohnen (2009) analyze the case of Canada in 2002-04, finding that firms that benefited from R&D grants introduced more new products, including more world-first innovations.⁵ Foreman-Peck (2013) studied UK manufacturing and service firms in the same period, showing that publicly-supported firms were more likely to introduce new products or processes. In the United States, Smith (2020) found that firms granted funding by the “Advanced Technology Program” between 1998 and 2000 announced more new products in the following years (2001-14). Similarly, van der Have and Deschryvere (2026) study R&D grants in Finland between 1997 and 2018, showing that publicly supported firms were much more likely to introduce innovations in the following years. This last article is the closest to ours, since it also uses an LBIO database to identify innovations.

In the context of this literature, our paper aims to make a number of significant contributions. First, we argue that it is important to look further than into the effects on firms: precisely because innovation may have important externalities, some of the positive effects might not be captured by firms. We use innovations themselves, coming from a rather unique source which has not been previously used for this purpose. To the extent of our knowledge, this will be the first study to approach additionality with a LBIO-based database of significant innovations, other than the recent article by van der Have and Deschryvere (2026).⁶ In difference to van der Have and Deschryvere (2026), we are able to directly link innovations (instead of firms) to public funding projects. Second, we consider a longer time frame than that of many studies. A few years or even a decade might not be enough to capture the effects of public funding. We have three decades of data, which allows us to look at long projects and to explore changes through time in the Swedish innovation landscape.⁷ Third, we use data on rejected applicants in order to construct a robust control group. This approach has been used by a number of studies but it is still not the most common, as the data is often difficult to obtain.

⁵These firms are compared with other firms receiving no grants, but both groups get support in the form of R&D tax credits.

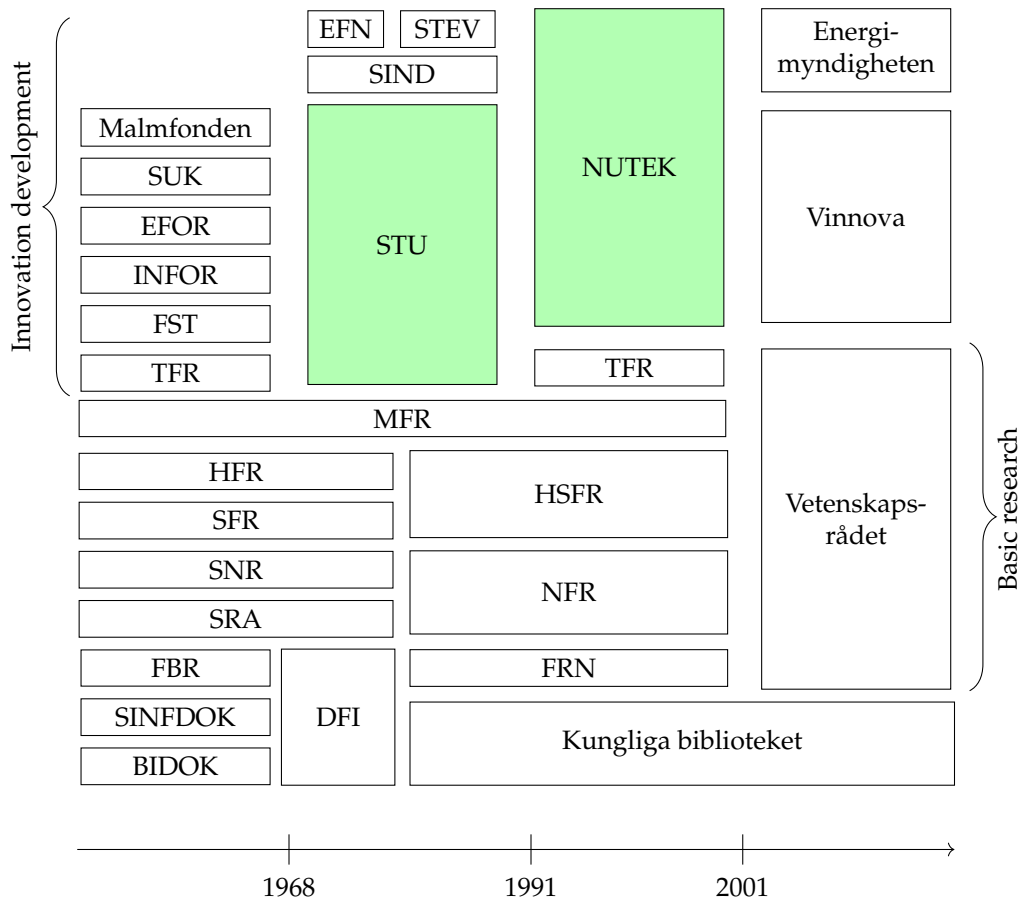
⁶LBIO means *Literature-Based Innovation Output*, and it is the method used to collect our innovation data. See further explanations in section 4.

⁷Indeed, the average difference between being funded and appearing in Swinno amounts to 3.3 years in our data, but there is are 92 innovations (17.7%) where this number is higher than 5, a longer time period than that covered in most studies.

3 Public innovation funding in Sweden

The Swedish public funding system underwent frequent changes and restructuring during the observation period (Åström et al., 2011; Fink and Taalbi, 2024). Alone the main innovation agency changed three times between 1968 and 2001. An overview over the Swedish public funding landscape is presented in table 1.

Figure 1: The public funding landscape



Source: author's elaboration.

Notes Funding years were slightly adjusted. For example, Malmfonden was listed as a separate agency until 1971 and Energimyndigheten was established in 1998. Colored areas mark funding organizations included in our data set.

The Board for Technical Development (*Styrelsen för teknisk utveckling* STU) was established in 1968 as Sweden's first central innovation agency (Sveriges Riks-

dag, 1968). It is generally considered an early example for a second-generation innovation agency (Arnold and Barker, 2022), where funds were no longer only directed towards basic research but rather towards applied research and product development. STU's purpose was described as follows:

"It is proposed to establish the Board for Technical Development, a central agency for this kind of support, on the 1st of July 1968. The board is intended to take over tasks from the Technical research council [TFR], Malmfonden, INFOR, EFOR, and the Swedish inventor's office. [...]"

*Apart from funding, STU should conduct certain service activities, among others guidance for inventors, researchers, and dissemination of research results. STU shall have a planning and coordinating function regarding international technical collaboration, information, documentation, as well as certain research stations. A separate council shall coordinate all scientific information and documentation."*⁸

During the early years of STU's existence, organizational issues constrained its efficiency. STU took over responsibilities from multiple agencies, including the TFR (*Statens Tekniska Forskningsrådet*), EFOR (*Stiftelsen för Exploatering av Forskningsresultat*), INFOR (*Institutet för Nyttiggörande av Forskningsresultat*), *Malmfonden*, and the Swedish inventor's office SUK (*Svenska Uppfinnarkontoret*).⁹ The integration of six separate agencies into a single one did not go smoothly. Some competencies, especially administrative capacities, were in over-supply while others were absent and needed to be built up (Weinberger, 1997, pp. 385-395).

The situation was even more charged between the 19 expert committees (*facknämnder*)¹⁰ of which STU consisted in its early days (Weinberger, 1997, pp. 385-395). Expert committees operated basically independently, as they held full authority to make decisions on projects as long as they stayed within their budget. As each committee struggled to maintain its share in total STU funds, committees frequently threatened to push for independence if they perceived that other committees were favored over them. Weinberger (1997, p. 389) goes so far as describing the situation as an internal "civil war". To resolve these

⁸Own translation from Government Bill 1968:68.

⁹TFR: founded in 1942 with the purpose to support long-term projects unfeasible for single companies in the area of technical basic research (Arnold and Barker, 2022; Weinberger, 1997, pp. 89-92). INFOR and EFOR: founded in 1963 and 1964 respectively, they fostered the commercialization of research findings (Sveriges Riksdag, 1964). *Malmfonden*: created in 1961 with the purpose to support large, long-term research projects with industry connection falling outside the scope of the research council (Sveriges Riksdag, 1961). SUK: established in 1947, it provided general support for inventors, as well as information on patenting (Riksarkivet, 2022).

¹⁰Separate expert committees existed for the areas of general technical development, biotechnology, medical technology, technical-industrial, inventors, applied mathematics (incl. information processing and computer technology), transportation, material science, geotechnology, astronautics, flutists, electronic components, aeronautics, disability aids, marine technology, remote-sensing, teaching, desalination, and nuclear research (SOU, 1977, p. 21).

conflicts an internal reorganization of STU took place in 1972 (Weinberger, 1997, p. 390). These internal conflicts affected even book-keeping and documentation, as comprehensive data catalogs are only available from 1972 onwards.

In 1972 the expert committees were transformed into "areas of need" (*behovsombörden*) and had merely an advisory function, with project decisions instead taken by case managers. The creation of the "areas of need" is in line with Sweden's tradition of sectoral research programs dating back to the 1960s. Public funding was especially during the 1960s and 70s directed towards materials, production and forestry (Åström et al., 2011; Arnold and Barker, 2022; Eklund, 2007, p. 92). From the 1980s onwards, information and biotechnology become of major importance (Soete and Freeman, 2012; Eklund, 2007, pp. 72-77).

A series of external evaluation investigated the efficiency of STU's work throughout its existence (SOU, 1977; Weinberger, 1997, pp. 454-456, 460-463). Especially during the 1970s, these pointed out several weaknesses of STU, such as the lack of both coordination between projects and long-term finance, as well as insufficient follow-ups of approved projects (Arnold and Barker, 2022; SOU, 1977, pp. 224-225). In reaction to this, STU established framework programs (*ramprogram*) in 1977, with the aim to provide long-term funding for projects in target areas, and to foster long-term collaboration (Weinberger, 1997, pp. 427-432). Moreover, detailed peer reviews were introduced in 1979 with the purpose to ensure high scientific quality and ensure coordination across projects (Arnold and Barker, 2022).

STU was replaced by the the Agency for Technical and Industrial Development (*Närings- och teknikutvecklingsverket* NUTEK) in 1991. While STU existed in parallel with separate organizations for the energy sector (*Energiforskningsnämnd* EFN and *Statens energiverket* STEV) and for regional development (*Statens industriverket* SIND), NUTEK took over all three organizations' responsibilities, involving the creation of a combined innovation, energy, business support, and regional development agency (Arnold and Barker, 2022). A special aim of NUTEK was the fostering of innovation networks, particularly of connections between small and medium sized enterprises (SMEs) and universities (Rolfstam and Ågren, 2013; Eklund, 2007, p. 78).

It is no coincidence that the reorganization of the innovation agency took place in the same year as the power shift from the Social democratic party to the Center-conservative government in the midst of the Scandinavian Banking Crisis in 1991. According to Arnold and Barker (2022), the Center-conservative government believed it would only stay in office for a single term, rushing to restructure Swedish industrial and research policy. STU had been established under Social Democratic rule and had ever since its establishment been unpopular among conservatives. With the establishment of STU the Center-conservative coalition aimed to re-establish the power of universities and researchers over

research funding. Further, they privatized 10 funding foundations to prevent future public micro-management of research grants.

Nonetheless, combining all different innovation-related agencies in a single one did not diminish the debate around an effective restructuring of the public funding system during the 1990s (Eklund, 2007, pp. 85-136). Proponents of the innovation systems literature criticized the lacking regard for the actual nature of technical change in neoclassical economic thinking. Edquist (1993) voiced the need to establish an innovation agency that took the complexity of innovation systems into account. This was realized with the public funding reform of 2001 during which responsibilities for the development of innovation were taken over by Vinnova (*Verket for Innovationssystem*), Sweden's incumbent innovation agency at the time of writing. Since data protection laws prevent Vinnova from publishing information on non-approved projects, the year 2001 marks the end of our analysis.

It should be noted that the responsibility to foster the development of energy innovation was outsourced to the Swedish energy agency (*Energimyndigheten*) in 1998 (Åström et al., 2011). Data from Energimyndigheten is available, but only includes approved projects. Thus, it can only be utilized for part of our analysis, and energy-related projects are most likely underrepresented during the final three years of our research period. This concern also applies to the earlier years where the EFN and STEV existed in parallel with STU.¹¹ However, findings from Fink (2026) detect a significant drop in energy innovation funding provided by main innovation agencies only around the time that Energimyndigheten was established.¹² Previous restructuring of public funding institutions for energy innovation had no similar effect.

4 Data

This article combines data from various sources. The first is SWINNO, a database of significant innovations in the Swedish economy. The second is a novel database of projects applying for public funding (both approved and rejected projects). These two are linked to identify which innovations in SWINNO applied for public funding for their development, and in such case whether

¹¹We searched the National Archives for similar project registries from STEV and EFN, as we found for main innovation agencies. However, project registries were far more fragmented as for main innovation agencies and contained far smaller number of projects. The project registry from EFN consists of a single volume (D1) for 1982-1990, while STU had 8 volumes between 1972-1978. For STEV, there exist two digital registries 1983-1987 and 1988-1991 (D9-D10). Therefore, we opted to not include them in the final public funding dataset.

¹²Funding for energy innovation provided by NUTEK/Vinnova dropped by approximately 50% between 1998 and 2002.

they obtained it. Finally, for the regression analysis these data is combined with some additional variables, which are described last.

4.1 Significant Swedish Innovations: SWINNO

SWINNO is a database of significant innovations developed in Sweden between 1970 and 2021 (Sjöo et al., 2014; Kander et al., 2019), which has been constructed based on the Literature Based Innovation Output (LBIO) approach. This approach entails the screening on trade journals, which aim to report on technological developments in their respective fields, for information on recently commercialized innovations. Innovations identified in this way are considered as significant since the editors are knowledgeable in their field of expertise and therefore able to identify the product introductions and developments with high degrees of novelty and economic significance. One advantage of LBIO over other approaches often used, like surveys, is that it tends to provide a better representation of small firm activity.

The latest release of SWINNO contains 4,838 innovations, commercialized between 1970 and 2021 (the first covered until 2014). Because inclusion in SWINNO is based on the criteria of innovations being recognized by editors of trade journals, we expect SWINNO to include the most significant Swedish innovations of the period, and therefore to represent some "top of the iceberg" in the innovation landscape. Thus, it covers a non-random subset of total innovations in Sweden. Patents could be an alternative to SWINNO as a source for innovation data. However, patent data would be less appropriate for our approach as patenting propensity is highly sector-specific and not all patented products and processes are commercialized (Pless et al., 2020; Taalbi, 2025). SWINNO has been recently compared with patent data, showing that only 43.9% of innovations were patented, and that the patent system would capture only 15% of all information about innovations included in SWINNO (Taalbi, 2025). In this paper, we therefore do not use patents to identify innovations, but we do include the existence of an innovation being patented prior to commercialization as a control variable in parts of our analysis.

For each innovation, the database contains a description, information on the innovating firms, the year of commercialization, product codes, level of market novelty, etc. A total of 948 innovations in SWINNO, corresponding to 19.6%, have been reported as being developed in collaboration. For collaborators information on their names, location on the national level, type, and firm id is included. Collaboration data from SWINNO has been analyzed in previous network studies (Taalbi, 2017; Chaminade, 2022; Bucaioni et al., 2025; Kreutzer and Taalbi, 2026). Innovating firm names have been linked to Statistics Sweden firm data (these data is introduced in section 4.4). SWINNO also includes a

variable indicating whether public funding is known to have been obtained, which applies to 6.3% of innovations in the database. However, we know that the LBIO method might significantly under-estimate the extent of public funding received. In the SWINNO database, Torregrosa-Hetland et al. (2019) estimated that public funding was underestimated by a factor of 4. This result was later supported by Fink and Taalbi (2024), who showed that the share of publicly funded innovations in SWINNO amounts to 24.1% instead of 6.3%. Innovations in SWINNO have been classified in terms of radicalness or degree of significance by Fink and Taalbi (2024), combining information on market novelty, firm novelty, and the number of trade journal sources. In this paper, we use their definition of *highly significant innovations* to distinguish innovations that were reported at least three times, or were reported twice but were new to the world market or radical from the firm perspective. This definition of ex-ante high significance has been compared to alternative definitions of ex-post significance by Fink and Taalbi (2024), showing high coincidence.¹³ In the present analysis, for subquestions 1 and 3 alternative regressions are presented where the components of significance are disaggregated.

4.2 Public Funding Database

Data on public funding projects has been obtained from two innovation agencies that operated during the study period: STU (1968-1991) and NUTEK (1991-2001). The data was gathered from two different sources, as shown in table 1. STINS is a digital database containing information on public funding projects of both agencies, but it only starts in 1979, so data from the first decade of STU's operation has been manually digitized from archival sources in the Swedish National Archives (*Riksarkivet*). Information for the period after 2001 is merely available for approved public funding projects due to data protection restrictions, so it cannot be included in the analysis. For the same reason, we could not incorporate data from *Energimyndigheten*, which might lead to some under-representation of the energy sector after *Energimyndigheten* was established in 1998.

The resulting Public Funding Database contains 62,114 public funding projects and information on a wide range of variables. Similar to SWINNO, each public funding project contains a detailed description, collaboration partners, owner-

¹³Fink and Taalbi (2024) present three alternative definitions of ex-post significance, based on innovations identified in the literature (Wallmark and McQueen, 1991; Sedig and Olson, 2002; Krutmeijer, 2013; Berggren and Krutmeijer, 2023), innovations with own Wikipedia pages, and winners of the Polhem price. The Polhem price is awarded since 1878, and today among the most prestigious technical awards. It is directed towards high level environmental innovation (Polhempriset, 2026).

Table 1: Public Funding Database sources

	Time	Observations	Source
STU	1972-1978	10,576	Riksarkivet - Manually digitized
STINS	1979-2001	51,538	Digital Source from Riksarkivet
Total	1972-2001	62,114	

ship status of applicant firms, sector and location information, etc. It additionally includes dates of decision, start and end of the projects, as well as applied and granted amounts.¹⁴ To ensure comparability over time all monetary values have been expressed in 2020 SEK based on inflation data from Statistics Sweden (2025).

The raw data included 5,587 additional observations. Nonetheless, public funding projects were excluded if targeted towards non-innovation or non-project specific activities, such as conference and travel costs, culture, social science, regional development, and general non-project specific research activities.

Figure 2 shows the number of applications and approved projects per year in the Public Funding Database. Both lines have an inverse-U shape. The innovation agencies received about 1,000 project applications per year in 1972-75, close to 3,000 per year in the 1980s and below 1,000 per year in the second half of the nineties. The maximum of 4,094 projects was attained in 1981. The number of approved projects oscillates less, with values around 2,000 in the central part of the period and below 200 since 1995.

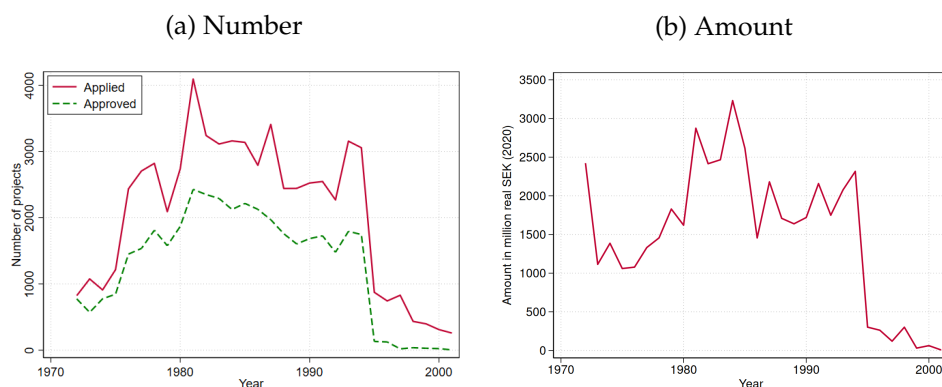
Of course, the combination of these two series yields an approval rate with significant changes over time (see figure 3). During STU's initial years, chances of approval were very high, and after some oscillation they remained at approximately 70% until the late 1980s. In the last part of the period, they rapidly declined to less than 20% from 1995 onwards. The initial gradual decline in approval rates (1990-94) corresponds to a temporary rise in the number of applications combined with a relatively constant number of approved projects per year, while the second, more abrupt drop is related to the significant cut in the number of approved projects due to reduced funding.¹⁵ Recall the description in section 3 about the public funding bodies and their decision-making processes, which were very lax at the beginning of the period.

The figure also shows total granted amounts per year. These fluctuate at around

¹⁴Granted amounts refer here to the amounts that the funding organizations approved (*beviljat*). They might exceed paid out amounts (*utbetalt*) in case that granted amounts were not fully used, or paid back to innovation agencies (*återfört*).

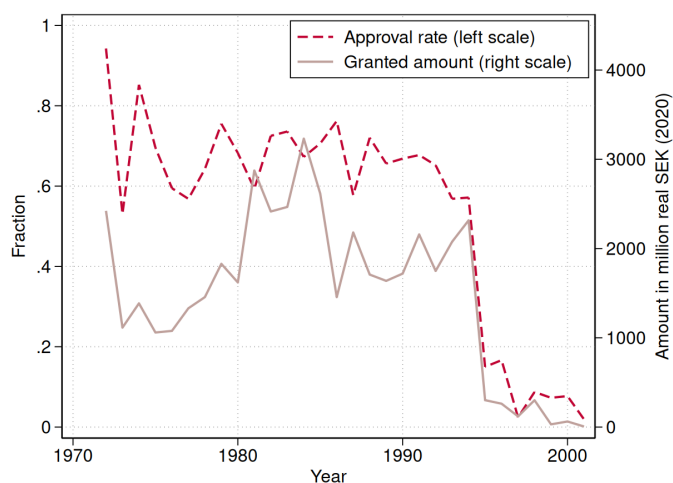
¹⁵Because of these important changes over time, we conduct some separate analyses by decade as robustness checks.

Figure 2: Amount and number of public funding projects, 1972-2001



Source: Public Funding Database.

Figure 3: Public funding projects: rate of approval and total amounts granted, 1972-2001



Source: Public Funding Database.

2 billion SEK annually, falling to below 200 million SEK in 1995 and onwards. Granted funding was significantly higher in the early 1980s, where it reaches a maximum of 3.25 billion in 1984. The sharp drop in both approval rates and granted amounts can be easily related to the economic crisis that the Swedish economy underwent during the 1990s. The Swedish government faced severe fiscal constraints and NUTEK's budget was cut by approximately 50% between 1995 and 1996 (Jonung et al., 2009; Eklund, 2007, p. 101).

The approval rates shown above can be compared with those from other studies on the Swedish innovation public funding bodies. For example, Norrman and Bager-Sjögren (2010) use data from the Swedish Innovation Center (1994-2003)¹⁶ in which only 93 out of 603 firms were rejected from the program (approval rate of 84.6%). This is data cleaned after removing applications with not enough information, errors, applications out of the scope of the program, etc. The authors interpreted this result as strong self-selection. Because of the way the application system worked, firms that firms with low success chances would realize this ex ante and not submit their applications. In contrast, the Swedish program *Forska & Våx*, which started in 2006, seems to have given funds to 20% of applicants (Svensson, 2011, cited in Daunfeldt et al., 2016). Similarly, the *Vinn Nu* program analyzed in Söderblom et al. (2015) received a total of 1,102 applications during 2002-08, out of which 130 were successful (a 11.8% approval rate). In this case, the process is described as around half the applications rejected at the onset, then sent to external review and retaining those with the highest scores, then internal decision based on those and fitting to 24 max yearly awarded. With respect to other contexts, Mina et al. (2021) work on the European Commission Horizon 2020 SME Instrument, which is shown to be very competitive, with 8.4% and 5.5% approval rates for its two first phases in 2014-17. In the United States, the SBIR program received between 1995 and 2013 a total of 9,659 applications from 4,545 firms for Phase 1. The result was of 1.7 awards per competition with 11 firms competing for each award on average, which implies a success rate of 15.5% in phase 1 (Howell, 2017).

4.3 The combined database

The linking of projects from the Public Funding Database to those in SWINNO was one of the major challenges in this study, due to the sheer size of the Public Funding Database. This process was first presented in Fink and Taalbi (2024), where it was used to link the approved projects to SWINNO. We follow the same approach to link the non-approved projects.

To reduce the number of potential links, the first step is to screen the Public Funding Database for name(s) of the innovating firm(s) and innovation names present in SWINNO. All projects returned by this search, with a start year differing by a maximum of 10 years from the commercialization year, are considered as potential matches.¹⁷ In the second step, the descriptions of the innovation in

¹⁶Stiftelsen Innovationscentrum is one of the foundations privatized under the center-conservative government. Since the government cannot direct its activities it is not considered in the present study (Sveriges Riksdag, 1993).

¹⁷On average there exists a 3.3 year delay between a decision on a public funding project being made, and it turning into a significant innovation outcome.

SWINNO and the Public Funding Database are compared to determine whether they are likely to refer to the same innovation. This process is straightforward if the description in the Public Funding Database contains the innovation name, and/or keywords from the description in SWINNO. A detailed example is presented in Appendix B.

Next we provide information on the composition of our database, separately at the firm, innovation, and public funding project level. Table 2 shows the information compiled at the firm level. A total of 17,008 firms are considered in the final dataset. 1,520 of those are included in SWINNO. 15.7% of firms in SWINNO applied for public funding. The success rate for firms in SWINNO is 95.5%, compared to merely 51.7% among all firms included in the Public Funding Database.

Table 2: Observations classified: firms

In SWINNO?	Applied for public funding?		Got public funding?		Total
	Yes	No	Yes	No	
Yes	238	1,282	154	84	1,520
No	16,770	-	7,505	9,265	-
Total	17,008	-	8,787	9,349	-

Source: Public Funding Database.

Notes: The data includes research institutes along with actual firms. They are kept in the database because they also often act as innovators. We use the term ‘firms’ as a simplification.

Table 3 shows the innovations in SWINNO classified according to whether they are associated with applications for public funding, and whether these applications were successful. 441 out of a total of 2,865 innovations can be directly linked to public funding projects. Among these, 412 innovations (corresponding to 93.4%) were approved.

Table 4 displays approval and linkages to SWINNO among public funding projects. Direct links to SWINNO are presented in rows, while the columns show approval rates. According to this information, the approval rate of projects for public funding was quite high. Out of 62,037 applications, 38,875 were successful, which implies a success rate of 62.7% on average throughout the period. While the overall probability of being directly linked to SWINNO is merely 1.4%, approval rates for these projects amount to 80.9%, approximately 18 percentage points higher than for non-linked projects.

Table 3: Observations classified: innovations

Applied for public funding?		Got public funding?		Total
Yes	No	Yes	No	
441	2,424	412	29	2,865

Source: Public Funding Database.

Notes: For some innovations in Swinno we know that they got public funding according to LBIO, but we have not been able to find the links in the public funding database.

Table 4: Observations classified: public funding projects

Linked to Swinno?	Got public funding?		Total
	Yes	No	
Yes	707	167	874
No	38,168	22,995	61,163
Total	38,875	23,162	62,037

Source: Public Funding Database.

Notes: For some innovations in SWINNO we know that they got public funding according to LBIO, but we have not been able to find the links in the Public Funding Database.

4.4 Control variables

Individual firms and organizations, referred to simply as firms, are a central part of the analysis. To account for past innovation activity and facilitate the matching of the two data sets, firm names have been cleaned for differences in spelling, and compiled on the concern level.

Information on ownership status is given by the binary variable *Public*, indicating firms which are under full or partial public ownership. Information on this variable is obtained both from SWINNO and the Public Funding Database.

Location controls are included, since major public funding programs in Sweden were targeted towards urban areas (Asheim and Moodysson, 2017). Location data refers to companies' head offices in Sweden. These have been included in either of the two databases as a separate variable or extracted from the company name. *Major city* is assigned to firms located in Stockholm, Göteborg, or Malmö, which have been consistently the three most populous cities in the country since the 1870s. *Medium city* applies to firms located in the top 20 biggest cities in Sweden in terms of population size as of 1970, taken from Bäcklund (1991).

The top three are excluded from this category. The omitted category are firms located in small cities, which refers to all other locations in this study.

The literature has identified firm size as an important determinant of innovation activity and reliance on public resources. Since most traditional forms of firm finance are geared towards large firms, SMEs are to a higher extent dependent on public funding (Asheim and Moodysson, 2017; Lerner and Tåg, 2013; Fink and Taalbi, 2024). This applies especially to the 1970s and 1980s, before venture capital became widely available in Sweden (Dahlstrand and Cetindamar, 2000). Moreover, established firms are less likely to generate radical or highly significant innovation, since they mostly focus on optimizing their existing production rather than developing entirely new products (Dahlstrand and Cetindamar, 2000; Asheim and Moodysson, 2017).

Information on firm size is obtained from Statistics Sweden. The variable is reported by employment classes. Firms with less than 50 employees are classified as small, while those with 200 or more are considered to be large. Universities and university colleges (*högskola*) are classified as large when employment data is missing. Firm size data was not perfectly matched to firms in the Public Funding Database and in some cases in SWINNO due to small variation in the spelling of firm names. While this affects merely 9% and 7% of firms and innovations in SWINNO, respectively, linking firm size data to the Public Funding database proved more challenging. Exact matches were found for 4,493 firms which were involved in 42,812 public funding projects, corresponding to two-thirds of the sample. We therefore present alternative results with this matched subsample in section 6.2.

Because sector information was only available for about half of the public funding projects, we have classified the projects looking for keyword lists in the project descriptions, to match the SNI 2007 official classification at the letter level. The keyword lists were generated using Gemini, through an iterative process, resorting to the descriptions of unclassified projects to improve. For example, projects were declared to correspond to SNI D "Electricity, gas, steam and air conditioning" if they included keywords such as *energi*, *elkraft*, *elektricitet*, or *solpanel* (and further related concepts).¹⁸ Currently, 14.6% of the innovation projects remain unclassified. While the SNI classification at the letter level includes a total of 21 categories, not all these are relevant for innovation projects. We work with 10 sectors, of which the most frequent in the data are "Manufacturing" (C), "Professional, scientific and technical activities" (M), and "Information and communication" (J).¹⁹ A complete overview of the sectors,

¹⁸We combined keywords in Swedish and English, since project descriptions often mix both languages.

¹⁹The rest of the sectors we contemplate, with the abbreviated names we use in the paper, are: Energy (D), Construction (F), Health (Q), Transportation and storage (H), Water and waste (E),

including a subset of keywords on which we classify them, is presented in table 11. For consistency the same definition of sectors has been applied to classify innovations in SWINNO.

This study does not address the debate surrounding the potential crowding out of private R&D funding, since there is no data available on private funds at the innovation level.

5 Methodology

5.1 Q1: What innovative firms apply for public funding?

The first question addressed in this paper is which innovative firms apply for public funding. With innovative firms, we refer to any firm or organization engaged in the development of an innovation included in the SWINNO database. It should be clear that we do not exactly deal with "selection" into applying for public funding, since we depart from an ex-post situation. Our sample are the firms which have had at least one innovation project included in SWINNO: they succeeded in generating a new product that attracted attention in a trade journal. We do not have information about other firms, which might also have considered applying for funding, either got it or not, and did not generate such a significant innovation. What we can do here, therefore, is characterize those firms within SWINNO who had applied for public support for these innovations.²⁰

To address this question, a logit model is used, measuring the probability of the developing firm(s) to apply for public funding ($Apply_{ijt}$) based on a number of covariates X_{ijt} .²¹ Since one firm might have several innovations listed in SWINNO, all covariates are binary variables defined at the level of the particular innovation project.

$$\begin{aligned} \text{logit}(E[Apply_{ijt} | X_{ijt}]) = & \alpha + \beta_1 Public_{jt} + \beta_2 [\sum_{t_z < t}^{t-1} Approval_{j,t_z} \neq 0] + \\ & \beta_3 [\sum_{t_z < t}^{t-1} Innovation_{j,t_z} \neq 0] + \beta_4 Small_{jt} + \beta_5 Large_{jt} + \beta_6 Medium_{jt} + \\ & \beta_7 Major_{jt} + \beta_8 Collaboration_{it} + \beta_9 Patented_{it} + \beta_{10} High\ Significance_{it} + \\ & \beta_{11} \Delta GDP_t + \gamma_i + \delta_t + \varepsilon_{ijt}, \end{aligned} \quad (1)$$

The logistic regression model is presented in equation 1. The model consists

Agriculture, forestry and fishing (A), and Other. We use "Professional services" hereafter to refer to category M.

²⁰Of course, since we will later look at the effects of public funding for the generation of successful innovations, actual inclusion in SWINNO is influenced by the application decision (and the funding decision).

²¹The same variables are used in OLS and Probit regressions run as a robustness exercise.

of firm and innovation characteristics. i denotes the innovation, j the developing firm, and t the commercialization year. As firm characteristics we include information on ownership, previous access to public funding and innovation activity, as well as on location and firm size. $Public_{jt}$ specifies whether the firm is partially or totally publicly-owned at the time of commercialization. The development of innovations and access to public funding in the past is measured by $[\sum_{t_z < t}^{t-1} Approval_{j,t_z} \neq 0]$ and $[\sum_{t_z < t}^{t-1} Innovation_{j,t_z} \neq 0]$, respectively²². In addition, controls are included for firm size ($Small_{jt}$, $Large_{jt}$) and location ($Medium_{jt}$, $Major_{jt}$).

The second set of controls are defined on the innovation level. These indicate whether an innovation has been developed in collaboration ($Collaboration_{it}$), whether it has been patented before commercialization ($Patented_{it}$), and whether it has been classified as being of high significance ($High\ Significance_{it}$).

Finally, the equation contains controls for macroeconomic conditions ΔGDP_t , sector controls (γ_i) and time (δ_t) fixed effects. ε_{ijt} is the error term.

5.2 Q2: Are approved public funding projects more likely to translate into significant innovations?

Here, we deal with additionality: does public funding have the effect of generating more innovations? To operationalize it, we ask whether projects that were approved were more likely than similar non-approved projects to translate into significant innovations. That is, whether being funded makes a particular project more likely to be linked to an innovation in SWINNO. Both the treatment variable ($Approval$) and the outcome variable ($Swinno$) are binary.

For this question, we only use data on the funding agencies STU and NUTEK, because it is for them that we were able to obtain both the approved and the non-approved projects (remember section 4).

When we look at the observable characteristics of approved and non-approved projects, significant differences are found in almost all the variables: decision year, public ownership, past public funding, location in major towns, as well as several sector controls (see table 5). This confirms the need to construct a relevant comparison group. The whole sample of non-funded projects cannot be used as such.

To construct the control group, we proceed by matching, following the approach taken by other studies in the field (for example, Czarnitzki and Licht, 2006, or Czarnitzki and Hussinger, 2018). We use several alternative matching estimators, given that the literature shows no consensus about which one would be superior to others (Orlic et al., 2019).²³ We have run regressions with propensity-

²² $[\cdot]$ is an Iverson bracket taking the value 1 if the condition is fulfilled.

²³See Cerulli (2010) for a discussion of matching together with other methods.

Table 5: Differences between approved and non-approved projects

Variable	Non-approved (N=23,162)	Approved (N=38,875)	Diff	p-value
Applied amount (million 2020 SEK)	1.0246	1.1101	0.0855	0.1858
Decision year	1986.40	1984.15	-2.2457***	<0.001
Public ownership	0.2929	0.4052	0.1123***	<0.001
Past public funding	0.5955	0.7718	0.1763***	<0.001
Medium town	0.1328	0.1361	0.0032	0.2546
Major town	0.1398	0.1833	0.0434***	<0.001
<i>Sectors</i>				
Manufacturing	0.1530	0.1539	0.0008	0.7782
Professional services	0.1168	0.1013	-0.0155***	<0.001
Information and communications	0.2701	0.3621	0.0919***	<0.001
Energy	0.0752	0.0737	-0.0014	0.5150
Construction	0.0384	0.0398	0.0014	0.3810
Health	0.0274	0.0371	0.0097***	<0.001
Transport	0.0133	0.0156	0.0023**	0.0232
Water and waste	0.0158	0.0137	-0.0021**	0.0315
Agriculture, forestry and fishing	0.0109	0.0093	-0.0016**	0.0484
Other	0.2790	0.1935	-0.0855***	<0.001

Source: Public Funding Database.

Notes: Stars indicate significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

score matching (i.e., based on the probability of approval), nearest-neighbor matching (i.e., identifying the most similar observations in terms of a set of variables), and inverse probability weighting (weighting by the inverse of the propensity score).²⁴

Equation 2 presents the logit model used to calculate the propensity score (approval probability):

$$\begin{aligned}
 \text{logit}(E[\text{Approval}_{jkd} \mid X_{jkd}]) = & \alpha + \beta_1 \text{Amount}_{kd} + \beta_2 \text{Public}_{jkd} \\
 & + \beta_3 [\sum_{d_z < d}^{d-1} \text{Approval}_{j,d_z} \neq 0] + \beta_4 \text{Small}_{jd} + \beta_5 \text{Large}_{jd} \\
 & + \beta_6 \text{Medium}_{jd} + \beta_7 \text{Major}_{jd} + \gamma_k + \delta_d + \varepsilon_{jkd}.
 \end{aligned} \tag{2}$$

Equation 2 estimates the approval probability (Approval_{jkd}) of a project k , developed by firm j during decision year d . The variables included in the model are the applied amount (Amount_{kd}) (in million real SEK of 2020, logged), public ownership (Public_{jd}), past public funding ($[\sum_{d_z < d}^{d-1} \text{Approval}_{j,d_z} \neq 0]$), firm size (Small_{jd} , Large_{jd}), location in a medium or major city (Medium_{jd} , Major_{jd}).

²⁴Given that we have a large sample, for the propensity-score matching we apply a caliper of 0.10, more stringent than the default of 0.25. For the nearest-neighbor matching, we use exact matching on the time-period variable.

Sector (γ_k) and time (δ_d) fixed effects are also included. ε_{jkd} is the error term. The same variables are used for matching in the nearest-neighbor approach. All variable values are collapsed at the project level.

One important caveat is that we do not have information about private funding directed to the innovation project (this is not available in our database, and would be extremely cumbersome to obtain). Because the available private amounts might be related to the approval of an application, the absence of such variable could bias the results. However, we cannot establish the direction of such bias on theoretical grounds: innovation agencies could be both *more* and *less* likely to fund projects which already received substantial private amounts. Our approach to this problem is to control for as many variables as possible that could influence, also, how much private funding the project gets.

Once the control group is constructed, we calculate the Average Treatment Effect on the Treated, as the difference in the outcomes of the treated and the control group (see equation 3).

$$ATET = E(Swinno_1 - Swinno_0 | Approval = 1) \quad (3)$$

The treated projects are those in which $Approval = 1$. ATET is defined as the difference between their actual outcomes $Swinno_1$ and the counterfactual $Swinno_0$, which is obtained by estimating the outcome for the matched projects.²⁵

5.3 Q3: How is getting more funding translated into innovation significance?

The third question assesses whether getting more funding translates into innovations of higher significance. For this, we use the high significance variable constructed by Fink and Taalbi (2024), which captures innovations that received higher attention in the trade journals. This is, therefore, in some sense the *expected* importance of the innovation in the sector, but not economic significance in their actual use after some years.

In this part of the paper, we use only innovations in SWINNO which received public funding (i.e., which have been linked to one or multiple approved projects). We use a logistic regression model where *High Significance* is the binary outcome variable. Our independent variables of interest are log applied amount ($Amount_{ikt}$) and the ratio of the amount granted over the amount ap-

²⁵The estimate of ATET would not be equal to ATE because there is selection into approval, i.e., approved projects differ from non-approved ones. We estimate ATET because we want to assess additionality on the funded firms, whether public funding contributed to their innovation outputs. ATE would give us the expected effect of public funding also on projects that did not get funded and that are thus different in a whole set of characteristics.

plied ($Coverage_{ikt}$). All information is collapsed at the innovation level (see equation 4).

$$\begin{aligned} \text{logit}(E[High\ Significance_{ijkt} \mid X_{ijkt}]) = & \alpha + \beta_1 Amount_{ikt} + \beta_2 Coverage_{ikt} \\ & + \beta_3 [\sum_{t_z < t}^{t-1} Approval_{j,t_z} \neq 0] + \beta_4 [\sum_{t_z < t}^{t-1} Innovation_{j,t_z} \neq 0] + \beta_5 Collaboration_{it} \\ & + \beta_6 Public_{jt} + \beta_7 Large_{jt} + \beta_8 Small_{jt} + \beta_9 Medium_{jt} \\ & + \beta_{10} Major_{jt} + \beta_{11} \Delta GDP_t + \gamma_i + \delta_t + \varepsilon_{ijkt}. \end{aligned} \quad (4)$$

The control variables included are the same ones introduced in the previous equations, and refer to characteristics of both the project and the firm. Sector dummies are as in the first model (see equation 1) based on the innovation (γ_i), and time dummies are constructed for 5-year intervals based on the commercialization year (δ_t). ε_{ijkt} is the error term.

As mentioned earlier, we do not have data on the amount of private R&D funding dedicated to each innovation by the involved firms. This would affect the interpretation of a variable representing the amount of public funding received in our equation. Thus, we cannot establish causality in this part of the analysis. Instead, we introduce the amount applied for, together with the coverage ratio. The idea is that applications with higher amounts are signaling important projects, which are characterized by higher costs and risks in exchange for higher potential rewards (Mazzucato, 2013).

Because data on applied amounts is only available before 2001, we restrict our analysis to the period 1970-2001.

6 Results and discussion

6.1 Q1: What innovative firms apply for public funding?

The results of the logit regression on the characteristics of innovative firms that have applied for public funding are presented in table 6. The same table contains even a simple OLS regression for comparison. In columns (1) - (4), firm, innovation, sector, and time controls are stepwise added to the regression. Column (4) presents the full regression results.

Among the firm characteristics, applying for public funding is positively correlated with public ownership, past access to public funding, being a small firm, and having the headquarters in one of Sweden's major cities (Stockholm, Malmö, Göteborg). The determinant with the greatest magnitude is having previously obtained public funding, which increases the likelihood to apply by a factor of 5.78. On the other hand, large firms and those that had already developed innovations in the past are less likely to apply for public funding. These findings are in line with innovation literature discussing public funding

Table 6: Characteristics of innovative firms applying for public funding, 1970–2001

	Logistic regression (odds-ratios)				OLS regression			
	(1) Firm	(2) Innovation	(3) Sector	(4) Time	(5) Firm	(6) Innovation	(7) Sector	(8) Time
Public	1.084 (0.838)	1.182 (0.675)	1.133 (0.765)	1.173 (0.724)	1.018 (0.724)	1.037 (0.475)	1.032 (0.533)	1.036 (0.482)
Past innovation	0.498*** (0.000)	0.524*** (0.000)	0.524*** (0.000)	0.523*** (0.000)	0.868*** (0.000)	0.877*** (0.000)	0.877*** (0.000)	0.878*** (0.000)
Past funding	3.324*** (0.000)	3.504*** (0.000)	3.545*** (0.000)	3.602*** (0.000)	1.251*** (0.000)	1.260*** (0.000)	1.259*** (0.000)	1.264*** (0.000)
Small (<50)	2.972*** (0.000)	2.841*** (0.000)	2.814*** (0.000)	2.750*** (0.000)	1.273*** (0.000)	1.257*** (0.000)	1.254*** (0.000)	1.244*** (0.000)
Large (>200)	0.719 (0.127)	0.718 (0.131)	0.714 (0.129)	0.676* (0.085)	0.946** (0.032)	0.947** (0.035)	0.948** (0.039)	0.941** (0.018)
Medium city	0.809 (0.269)	0.776 (0.195)	0.787 (0.228)	0.762 (0.167)	0.959** (0.049)	0.952** (0.020)	0.955** (0.029)	0.945*** (0.008)
Major city	1.140 (0.748)	1.168 (0.711)	1.235 (0.636)	1.133 (0.792)	1.028 (0.589)	1.032 (0.543)	1.038 (0.462)	1.018 (0.721)
Collaboration		0.758* (0.082)	0.746* (0.069)	0.736* (0.057)		0.948*** (0.007)	0.947*** (0.005)	0.948*** (0.006)
Patented		1.454** (0.043)	1.474** (0.036)	1.716*** (0.004)		1.080*** (0.004)	1.081*** (0.003)	1.114*** (0.000)
High significance		1.814*** (0.000)	1.817*** (0.000)	2.076*** (0.000)		1.129*** (0.000)	1.129*** (0.000)	1.151*** (0.000)
Construction			2.210 (0.107)	2.260 (0.116)			1.117 (0.154)	1.110 (0.174)
Health care			1.585 (0.515)	1.558 (0.518)			1.056 (0.557)	1.055 (0.562)
Information			2.847*** (0.007)	2.695** (0.016)			1.167*** (0.003)	1.145*** (0.008)
Transport and storage			1.875 (0.377)	1.641 (0.495)			1.100 (0.397)	1.079 (0.493)
Waste and water			2.322 (0.191)	1.946 (0.310)			1.116 (0.284)	1.071 (0.501)
Professional services			2.457 (0.216)	3.365* (0.099)			1.129 (0.236)	1.179 (0.105)
Energy			3.985*** (0.008)	3.921** (0.017)			1.239*** (0.006)	1.216** (0.012)
Primary sector			3.239 (0.424)	3.143 (0.352)			1.240 (0.404)	1.213 (0.450)
Manufacturing			2.015 (0.150)	2.021 (0.172)			1.105 (0.116)	1.097 (0.142)
1975–1979				1.229 (0.398)				1.025 (0.444)
1980–1984				1.256 (0.342)				1.031 (0.331)
1985–1989				1.337 (0.298)				1.048 (0.172)
1990–1994				0.835 (0.504)				0.954 (0.209)
1995–2001				0.456*** (0.001)				0.859*** (0.000)
GDP growth				0.992 (0.778)				0.998 (0.632)
Constant	0.242*** (0.000)	0.218*** (0.000)	0.080*** (0.000)	0.085*** (0.000)	1.235*** (0.000)	1.213*** (0.000)	1.049 (0.412)	1.084 (0.198)
Observations	2660	2660	2660	2660	2660	2660	2660	2660
Pseudo R-sq	0.124	0.136	0.141	0.160				
R-sq					0.153	0.167	0.171	0.191

Notes: Baseline categories – Medium sized firm, medium and low significance, other sector, 1970–1974. Clustered standard errors on the firm level.

access and the availability of alternative sources. Higher application rates for public funding among small firms and novel inventors is most likely related to the Swedish venture capital system being targeted towards large established firms until the 1990s (Dahlstrand and Cetindamar, 2000; Lerner and Tåg, 2013). Thus, SMEs only gained access to alternative forms of funding towards the end of the observation period.²⁶

With respect to the innovation-level characteristics, highly significant innovations and those that had been patented before commercialization are twice and 1.63 times as likely to be linked to public funding applications. Innovations developed by multiple firms are instead less frequently linked to public funding applications. This would indicate that more ambitious projects would have a greater need for public support (Mazzucato, 2013). Literature on innovation networks suggests that one of the main purposes of collaborative innovation activity is the possibility to pool financial resources (Burt, 1992; Roberts, 2000). Thus, it might serve as an alternative source of funding.

We furthermore detect significant differences in application propensity across sectors. Compared to the reference category ("other sectors"), innovations in the energy, construction, manufacturing, professional services, and information and communication sectors are significantly more likely to apply for public funding. For innovations from the construction and energy sector this effect amounts to more than a factor of 10. This result is in line with the general set up of public innovation funding in Sweden, where funds are directed towards "areas of need" (Åström et al., 2011; Soete and Freeman, 2012; Arnold and Barker, 2022; Eklund, 2007, p. 92).²⁷ Moreover, the particularly high propensity to apply for public funding in the energy sector can be accounted to the extended development times and higher risks associated with developing new energy technologies (Mazzucato, 2015; Gallagher et al., 2012; Fouquet and Pearson, 2012; Pless et al., 2020).

The goodness of fit of the logit regression (0.160) is slightly below but close to the threshold for being considered good in social science literature.²⁸

6.2 Q2: Are approved public funding projects more likely to translate into significant innovations?

We first run linear regressions and simple probit and logit regressions. Their results can be seen in Appendix E. The results of these are consistent with our

²⁶This would be consistent with the only period showing significant results being the post-1995 period, with lower application propensities (but of course it was also a period with lower budgets in the innovation agency).

²⁷*Behovsområden*.

²⁸Hemmert et al. (2018) give the reference of 0.2-0.4 being good, over 0.4 excellent.

preferred matching approaches in that they all show significant and positive effects of *Approval* on *Swinno*, controlling for all the other relevant variables. Propensity scores are calculated based on equation 2. These are then used to generate matches for our treated observations and produce an estimate of ATET with propensity-score matching. Secondly, we make a second matching estimate of ATET using nearest-neighbor matching (where observations are matched on the control variables instead of the propensity score). Finally, we go back to using the propensity scores to estimate the ATET with inverse probability weighting.

Results for the three approaches are given below. Before showing the ATET, we present the covariate balance in table 7. The table shows standardized differences and variance ratios between the raw and matched sample for the three models. After matching and weighting, the standardized differences are largely reduced, with the mean absolute difference going from 0.0899 to less than 0.0139 in all models.²⁹ The variance ratios also result close to 1, and within the 0.9-1.1 range in almost all variables. This indicates good matching quality. Both the standardized mean differences and the variance ratios show that the nearest-neighbor model works best, in terms of providing a balanced control group. Therefore, in what follows, we report results for the three models but consider nearest neighbor matching to give our preferred result.

The Average Treatment Effect on the Treated (ATET) estimated by the three models is shown in table 8. Treatment effects are strongly significant and remarkably robust across the three specifications. Our preferred result from nearest neighbor matching yields an ATET of 0.0098. This indicates that approved projects were 0.98 percentage points more likely to be linked to innovations in SWINNO. To put this number into perspective, we calculate relative effects: that is, we express the ATET in relation to *what would have been the probability of being in SWINNO for approved projects in absence of the public support*. This denominator is the counterfactual mean of the treated group, which we can obtain as the observed mean for the treated (percentage of approved observations in SWINNO from table 4: 1.82%) minus the estimated ATET. We calculate: $0.0182 - 0.0098 = 0.0084$. Thus, 0.0084 would be the probability of making it into SWINNO for the approved projects, in the absence of treatment. We use this number as our denominator to calculate the relative treatment effect as: $0.0098 / 0.0084 = 1.17$; a relative treatment effect of 117%. We may conclude that, for treated firms, public funding *more than doubled* their chances of delivering a significant innovation. Since SWINNO includes the most important innovations in the Swedish economy, we interpret this coefficient as strong evidence of output additionality, in

²⁹Rubin (2001) recommends using a threshold of 0.1 for adequate balance; below 0.05 would be considered excellent, which is also the case in most of our variables.

Table 7: Comprehensive Covariate Balance: Standardized Differences and Variance Ratios

Variable	Standardized Mean Difference				Variance Ratio			
	Raw	Model 1 (PSM)	Model 2 (NNM)	Model 3 (IPW)	Raw	Model 1 (PSM)	Model 2 (NNM)	Model 3 (IPW)
Applied (log)	0.0838	-0.1415	-0.0488	-0.0666	0.2711	0.5825	1.2629	0.3897
Public	0.2373	-0.0095	0.0297	0.0125	1.1638	0.9964	1.0125	1.0050
Past public funding	0.3860	0.0117	0.0072	0.0069	0.7312	0.9851	0.9908	0.9911
Medium city	0.0095	0.0062	0.0084	-0.0084	1.0205	1.0133	1.0181	0.9826
Major city	0.1182	-0.0018	0.0142	0.0201	1.2443	0.9971	1.0240	1.0342
1973	-0.0525	0.0004	0.0000	-0.0056	0.6814	1.0035	1.0000	0.9566
1974	0.1250	0.0002	0.0000	-0.0073	3.3633	1.0013	1.0000	0.9514
1975	0.0425	-0.0109	0.0000	-0.0042	1.3547	0.9321	1.0000	0.9730
1976	-0.0271	-0.0168	0.0000	-0.0025	0.8804	0.9231	1.0000	0.9880
1977	-0.0530	-0.0032	0.0000	-0.0082	0.7914	0.9852	1.0000	0.9622
1978	0.0148	0.0069	0.0000	-0.0036	1.0670	1.0304	1.0000	0.9849
1979	0.1064	0.0480	0.0000	0.0182	1.8026	1.2708	1.0000	1.0909
1980	0.0520	0.0338	0.0000	0.0278	1.2660	1.1611	1.0000	1.1296
1981	-0.0378	0.0090	0.0000	0.0239	0.8772	1.0335	1.0000	1.0929
1982	0.1015	-0.0019	0.0000	0.0150	1.5355	0.9929	1.0000	1.0580
1983	0.1104	-0.0008	0.0000	0.0131	1.6176	0.9971	1.0000	1.0510
1984	0.0463	-0.0214	0.0000	-0.0065	1.2121	0.9216	1.0000	0.9750
1985	0.0802	0.0074	0.0000	-0.0177	1.4063	1.0288	1.0000	0.9360
1986	0.1302	-0.0274	0.0000	-0.0222	1.8538	0.9013	1.0000	0.9189
1987	-0.0500	-0.0168	0.0000	-0.0117	0.8247	0.9347	1.0000	0.9539
1988	0.0832	-0.0001	0.0000	-0.0032	1.5095	0.9995	1.0000	0.9862
1989	0.0261	0.0012	0.0000	0.0009	1.1331	1.0054	1.0000	1.0044
1990	0.0368	-0.0134	0.0000	-0.0016	1.1898	0.9425	1.0000	0.9931
1991	0.0457	-0.0186	0.0000	-0.0053	1.2409	0.9228	1.0000	0.9770
1992	0.0211	-0.0061	0.0000	0.0004	1.1109	0.9710	1.0000	1.0018
1993	-0.0568	0.0094	0.0000	-0.0070	0.7953	1.0421	1.0000	0.9705
1994	-0.0536	0.0322	0.0000	0.0002	0.8023	1.1594	1.0000	1.0008
1995	-0.2189	0.0022	0.0000	0.0008	0.1082	1.0395	1.0000	1.0141
1996	-0.1940	-0.0027	0.0000	0.0006	0.1244	0.9547	1.0000	1.0100
1997	-0.2633	-0.0083	0.0000	-0.0002	0.0152	0.7144	1.0000	0.9928
1998	-0.1712	-0.0024	0.0000	-0.0007	0.0580	0.9269	1.0000	0.9793
1999	-0.1676	0.0010	0.0000	-0.0005	0.0475	1.0357	1.0000	0.9812
2000	-0.1469	0.0091	0.0000	-0.0002	0.0504	1.4997	1.0000	0.9918
2001	-0.1463	0.0051	0.0000	0.0001	0.0119	1.6666	1.0000	1.0128
Manufacturing	0.0023	-0.0113	0.0000	-0.0123	1.0045	0.9787	1.0000	0.9769
Prof. services	-0.0498	-0.0187	0.0036	-0.0019	0.8825	0.9527	1.0096	0.9951
Inf. and comm.	0.1987	0.0312	-0.0034	0.0225	1.1715	1.0192	0.9981	1.0135
Energy	-0.0054	0.0187	0.0000	0.0025	0.9826	1.0642	1.0000	1.0083
Construction	0.0073	-0.0005	0.0000	-0.0007	1.0353	0.9975	1.0000	0.9967
Health	0.0551	0.0127	0.0000	0.0035	1.3416	1.0655	1.0000	1.0176
Transport	0.0190	0.0080	0.0027	0.0126	1.1677	1.0657	1.0215	1.1062
Water and waste	-0.0177	0.0054	0.0000	0.0011	0.8672	1.0465	1.0000	1.0091
Agri., forestry, fishery	-0.0162	0.0063	0.0030	0.0019	0.8525	1.0676	1.0312	1.0202
Mean Absolute Diff.	0.0899	0.0139	0.0028	0.0089				
Max Absolute Diff.	0.3860	0.1415	0.0488	0.0666				

Table 8: Treatment effect of approval (ATET)

Estimator	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
PSM	.00957	.00147	6.50	0.000	.00668	.01246
NNM	.00980	.00176	5.56	0.000	.00635	.01325
IPW	.01052	.00105	10.05	0.000	.00847	.01258

Notes: Number of obs = 62,037; out of which 38,875 treated and 23,162 controls.

Source: author's calculations.

the sense that public funding contributed to the generation of significant innovations between 1972 and 2001. Importantly, innovations could have positive effects on the firms which introduce them, potentially leading to employment and growth effects. Spillover effects and externalities could even spread outside of the firm. We do not enter the discussion on the economic effects of these innovations; this might be a topic for further research. In any case, within the Swedish context, our study lies closer to the (positive) results of Söderblom et al. (2015) than to the (no) results of Daunfeldt et al. (2016), both reviewed in the literature section. These, however, refer to more recent innovation funding programs from the early 2000s.

Our positive additionality result is also in line with some studies from other geographic contexts (Bérubé and Mohnen, 2009; Hewitt-Dundas and Roper, 2010; Foreman-Peck, 2013; Smith, 2020; Prencipe et al., 2024). All these refer to a later period, always after the mid-1990s and mostly the early 21st century, and they use dependent variables taken from surveys, so there are important differences with respect to data. However, they all report positive output additionality. Bérubé and Mohnen (2009) shows that firms benefiting from both R&D grants and tax credits were more likely to introduce a "World first" innovation than those in the control group (matched firms only receiving tax credits): 25% versus 17%; thus the treatment effect can be identified as 8 percentage points, corresponding to 47%. Our result might seem quite large in comparison, but the different nature of the data should be considered here, since SWINNO is a very restricted set of innovations. Prencipe et al. (2024) estimate treatment effects of between 1 and 4 percentage points on the sales from new products, depending on the size of the firm; given the averages reported in the paper, these correspond to a percentage effect between 11 and 50% (results being higher for the large firms, with 250 to 500 thousand employees). Finally, van der Have and Deschryvere (2026) report an effect close to 10 percentage points in the probability of introducing an innovation (Finland, 1997-2018), with innovations also measured by LBIO. Their results, however, are difficult to compare to ours because the baseline probability of 0.09% refers to the whole population of

registered Finnish firms, and thus not only those conducting innovation activity and applying for public funding.

The reader might wonder if the fact that an innovation received public funding would make it more likely to be mentioned in the trade journals (independently of its importance). If this were true, the "effect" that we see would not be an effect on actually developing a significant innovation, but only on it being written about. However, from what we know about how trade journals work, this does not seem to be the case. In fact, the articles rarely mention the fact that public funding was obtained for a project, and as a result (as discussed in section 4) public funding is very under-represented in SWINNO (Torregrosa-Hetland et al., 2019; Fink and Taalbi, 2024).

What characterizes the projects for which public funding had positive effects? These were projects applying for lower quantities, and less likely publicly-owned (4.9 versus 37%) or previous receivers of public funding for their projects (51 versus 71%). They were less likely to be located in major cities. Benefited firms were more likely in Information and Communication, Water & Waste, and Transport; less in Health. The average year for benefiting firms is 1982.0, while that for non-benefiting is 1985.1, so earlier applications were more likely to experience positive effects.

Table 9 presents regression results for the subsample of projects where we have firm size data (42,797 projects, 69% of the original sample). Here, the precision of our PSM estimates is lower, but all the models provide significant and positive ATET. The estimated treatment effects are slightly lower in PSM and IPW, but not statistically different from our main results, and the NNM estimate is very close, at 0.99 percentage points. Since the baseline probability of being in SWINNO (approved projects) is higher in this subsample (2.19%), the relative treatment effect is lower, at 82.5% [$0.99 / (2.19 - 0.99)$].

Additionality was higher for small firms than for medium and large ones, as can be seen in table 9, where we have run the models separately by size. This result is consistent with the expectations from the literature, given the stronger funding constraints faced by small firms.

6.3 Q3: How is getting more funding translated into innovation significance?

The results regarding our third question are presented in table 10. Like in section 6.1, the logit estimates are compared to an OLS regression in the same table, and controls are added stepwise.

The estimated effect of the logarithm of the applied amount is positive and statistically significant at the 5% level. The estimate of 0.338 in column 4 indicates that a 1% increase in the applied amount increases the log-odds of

Table 9: Treatment effect of approval (ATET), subsample with size data

Estimator	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
All firms						
PSM	.00741	.00265	2.79000	0.00500	.00221	.01261
NNM	.00995	.00219	4.55000	0.00000	.00566	.01423
IPW	.00960	.00174	5.52000	0.00000	.00619	.01301
Small firms						
PSM	.01137	.00477	2.38000	0.01700	.00203	.02072
NNM	.01437	.00503	2.86000	0.00400	.00452	.009722
IPW	.01493	.00349	4.28000	0.00000	.00809	.02176
Non-small firms						
PSM	.00491	.00204	2.40000	0.01600	.00091	.00891
NNM	.00483	.00321	1.51000	0.13200	-.00145	.01112
IPW	.00635	.00229	2.77000	0.00600	.00186	.01084

Notes: Number of obs = 42,797 (14,294 small; 28,503 non-small); out of which 30,433 treated and 12,379 controls.

Source: author's calculations.

Table 10: Correlation between granted amount and innovation significance

	Logistic regression				OLS regression			
	(1) Innov.	(2) Firm	(3) Sector	(4) Time	(5) Innov.	(6) Firm	(7) Sector	(8) Time
Applied amount	1.293* (0.067)	1.453** (0.020)	1.483** (0.024)	1.435** (0.042)	1.043* (0.056)	1.063** (0.015)	1.066** (0.016)	1.062** (0.025)
Coverage	0.421 (0.307)	0.814 (0.862)	0.852 (0.898)	0.476 (0.646)	0.853 (0.285)	0.971 (0.871)	0.982 (0.921)	0.934 (0.752)
Controls								
Innovation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Sector	No	No	Yes	Yes	No	No	Yes	Yes
Time	No	No	No	Yes	No	No	No	Yes
Observations	215	186	173	173	215	186	186	186
Pseudo R-sq	0.057	0.080	0.092	0.137				
R-sq					0.060	0.083	0.117	0.156

Notes: Applied amount is in logged values.

producing a highly significant innovation by 0.34%. Evaluated at the sample mean probability (21%), doubling the amount of public funding applied for would be associated with an approximately 5.6 percentage points increase in the probability of producing a highly significant innovation, which can be considered modest.³⁰ This variable would signal more ambitious projects and not

³⁰Marginal effect: $0.01 \times \log\text{-coefficient} \times \text{baseline probability of high significance} = 0.01 \times \beta \times$

necessarily the effect of public funding itself, since we do not know the amounts of private funding directed to the innovations, as mentioned earlier.

The *Coverage* variable, which we were interested in as an indication of to what extent the public funding agency granted the amounts requested, does not attain statistical significance. This might be explained by small variation in this variable, as 86% of projects receive at least 90% of the funds that they applied for.

It must be acknowledged that the fit of these regressions is below the threshold normally considered good (our pseudo R^2 in the full regression is of 0.117, below the reference of 0.2 given in Hemmert et al., 2018). One explanation for this is the drop in sample size by over 95%, as only innovations that actually received public funding are considered here.

7 Concluding remarks

This study analyses the public innovation funding in Sweden between 1970 and 2001, and particularly its additionality effects. Data on public funding projects is obtained from the Swedish National Archives which has been linked to significant innovations in Sweden. Three questions have been addressed: (1) What innovative firms apply for public funding? (2) Are approved public funding projects more likely to translate into significant innovations? and (3) How is getting more funding translated into innovation significance?

First, we show that firms are more likely to apply for public funding if they are publicly owned, small, and located in major cities. Most importantly, they are very likely to keep applying for public funding if their applications have been approved in the past. This analysis is restricted to firms which have introduced significant innovations; therefore, we cannot fully assess selection into applying for public funding with the available data.

Second, we find strong evidence of public funding additionality. Approved projects were *more than twice* as likely than non-approved ones to translate into significant innovations.³¹ This result is very robust to diverse matching approaches, and to controlling for size with a subsample. The additionality effect was larger for small firms than for medium-sized and large ones, which would confirm the intuition in the literature that it is the first which are more constrained in terms of funding for their projects. In terms of change through time, the impact was greater during the 1980s, when the decision process was significantly revised and before drastic cuts in innovation agencies' budget during the following decade. This result points towards the importance of

$p(1 - p) = 0.01 * 0.338 * 0.21(1 - 0.21) = 0.00056$

³¹our estimate of the average treatment effect on the treated, in relative terms, is 117%

public funding when private funding availability is limited, since alternative funding in form of venture capital become only widely available from the 1990s onwards.

Third, we find that projects applying for higher amounts were more likely to generate highly significant or major innovations, defined as those with more mentions in the trade journals or a higher perceived novelty. This cannot be interpreted as a direct effect of the funding itself, since we lack data on private funding applied, but as an indication of the project's magnitude.

The paper provides a number of robustness tests, which confirm our main results. We provide simple OLS, probit and logit estimates. We exploit the variation in approval rates as an alternative for the matching approach, explore the amount to which the granted funds were used, and decompose significance into its three components.

Our results refer to Sweden, a country consistently ranked among the most innovative in Europe (Eurostat, 2022; Gasser et al., 2022). There is some literature pointing at positive additionality effects in other countries (for example, Bérubé and Mohnen, 2009; Prencipe et al., 2024; van der Have and Deschryvere, 2026), but the magnitude of the effects cannot be directly compared because of methodological differences. The impact we have found is very large, and we can only hope that future research would make such comparison possible. We would then have more elements with which to judge under what conditions public funding has positive effects on innovation output.

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Appendices

Appendix A Sector keywords

The table below presents examples of keywords using for classifying the sectors (not the full list).

Table 11: Sector definition

Sector		Keywords
A	Agriculture, forestry and fishing	jordbruk, skog, lantbruk odling, växt, fiske, gödsel, djurhållning
C	Manufacturing	tillverkning, produktion, industri, fabrik, verkstad, teknik
D	Energy	energi, energy, elhandel, kraft, värme, kyla, bränsle, förbränning
E	Water and Waste	vatten, avlopp, renhållning, avfall återvinning, sanering, recycling
F	Construction	bygg, entreprenad, anläggning, snickeri, måleri, fasad, fönster, renovering, ventilation
H	Transportation and storage	transport, logistik, lager, frakt, gods, leverans, distribution
J	Information and communication	mjukvara, software, it-konsult, programmering, kod, systemutveckling, app, webb, artificiell, nätverk, maskininlärning
M	Professional services	forskning, utveckling, innovation, analys, laboratorium, verifiering, rådgivning, redovisning
Q	Health	vård, omsorg, hälsa, terpi, sjuk, klinik, virus, operation

Appendix B Example of the linking process

In this section an example of the linking process between SWINNO and the Public Funding Database is presented.

Carbogel is described in SWINNO as an "environmentally friendly, coal-based fuel system [...] with properties similar to oil" ³². The project was developed in collaboration between AB Scaniainventor and Boliden, and was commercialized in 1980. To identify potential matches for this innovation, the Public Funding Database was scanned for projects linked to the two developing firms or including the innovation name.

- Developing firms: 27 and 53 potential matches were identified for AB Scaniainventor and Boliden, respectively. Out of these, 14 were excluded because the projects started a decade after the innovation was commercialized.
- Innovation name: one match was returned linked to AB Scaniainventor and two for project from Jernkontoret. Interestingly, Carbogel is also the name of a firm in the Public Funding Database. The 9 projects developed by this firm were also considered as potential matches.

In total, scanning for firm and innovation names produced 76 potential matches. From these I selected the most likely matches, by scanning the projects descriptions for keywords such as "coal (*kol*)", "coal paste (*kolpasta*)", or the innovation name Carbogel. Thereafter, 12 potential matches remain which are presented in table 12.

These 12 potential matches were closer inspected. Projects 8, 10, and 11 were declared matches, as they include the innovation name *Carbogel*, as well as terms such as heating, gasification (*förgasning*), and coal water (*kolvatten*), which all seem to be related to different applications of the innovation. Project 9 contains the term *Carbogel* but was not declared a match, as the description indicates a collaboration with the firm of the same name, rather than a relation to the innovation.

Among the remaining seven projects, projects 3, 4, 5, 6, and 7 all include the term coal paste (*kolpasta*). Thus, they refer with high certainty to the innovation in question. Projects 1 and 2 refer to "coal as an energy source"³³, nonetheless the descriptions do not indicate a clear link to the description of Carbogel in SWINNO, as the terms do not specifically refer to a coal-water mixture or coal paste. Thus, a total of 9 public funding projects were directly linked to Carbogel.

³²Own translation from original in Swedish.

³³Own translation from original in Swedish.

Table 12: Potential matches for Carbogel

	Firm	Description	Start	End	Amount	Appr.
1	Scaniainventor	Kol som energikälla. Undersökning angående ny metod för integration av hantering, distribution, konsumentlagring, förbränning och avgasrening	1974	1974	455,569	1
2	Carbogel	Kol som energikälla	1974	1975	455,569	1
3	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1975	1975	1,560	1
4	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1976	1977	3,007,967	1
5	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1976	1976	751,992	1
6	Carbogel	Kolpasta – utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1978		0	0
7	Carbogel	Utveckling av komplett system för användning av kol i form av kolpasta vid termisk energiomvandling	1978	1978	2,351,750	1
8	Scaniainventor	Carbogel Heating	1980	1983	1,196,756	1
9	Jernkontoret	Ämnesvärmning med Carbogel lab förs	1983		0	0
10	Jernkontoret	Förgasning av Carbogel	1983		0	0
11	Carbogel	Kolvatten Carbogel	1983	1984	0	0
12	Carbogel	Utveckling av teknik för produktion och karaktärisering av högrenade kolvattenbränslen (CAM)	1984	1986	9,853,537	1

Appendix C Robustness

In this section we conduct some additional analyses. We first estimate our main models separately for periods when the assessment procedures or the main innovation agency changed (STU 1: 1970-78, STU 2: 1979-90, NUTEK: 1991-2001). Second, we check for any differences in the effects of the components of the significance variable (Q1 and Q3). Thirdly, we exploit the information about the use of the granted funds by the firms, trying to see if the firms that did not use the money had lower effects (Q2). Finally, we exploit the variation in the approval rates (Q2), with the main aim to use the sharp drop in approval rates in the 1990s.³⁴

³⁴We have tried to use text notes available for 6,306 projects which had more information about the granting decision. One possible approach was to run a sentiment analysis on these texts, and use the sentiment score as a predictor of the approval of a project. However, this strategy was not possible because there was not enough variation in the sentiment scores of the projects.

C.1 Separating different periods

As discussed previously, the public funding system in Sweden underwent significant changes over time: in the selection mechanisms of approved projects, in the targeted firms and sectors, as well as fiscal restrictions following the Scandinavian banking crisis of the early nineties (Åström et al., 2011; Arnold and Barker, 2022; Jonung et al., 2009). The application and approval process underwent major changes. As discussed in Åström et al. (2011, pp. 30-34), public funding applications were only critically screened regarding their scientific quality from 1979 onwards. Previously, public funding was granted to the best applications as long as funds were sufficient. Connections between them were not considered. Furthermore, STU established in the late 1970s a system to systematically evaluate the results of previous projects, which affected decisions on project renewals and follow-up projects. Because of these differences, we break up our 31-year-long observation period by decade to get a deeper insight into changes across time. The final decade is extended by two years to include observations from 2000 and 2001.

Table 13 illustrates the regression results of innovative firms applying for public funding by decade. Overall, findings are very similar, with past funding having the stronger effects throughout, and positive associations of the application behavior with small firm size and high significance of the innovation. Some variation over the decades is that we do not find a significant effect of the *Public* nor *Major* variables in the 1980s, nor of the *Patented* variable in the 1990s. However, this could be related to the lower number of observations in the regressions by decade, which reduces estimation precision. The stronger likelihood of applications from the *Energy* sector is driven by the 1970s and 1990s, while that of *Construction* arises from the 1980s.

The effect of approval on generating significant innovation split by sub-periods is presented in table 14. Evidence of output additionality, indicated by a positive and significant ATET, can be clearly detected in the 1970s and 1980s, while with the data from the 1990s it does not attain significance in the propensity score and nearest neighbor matching approaches. Of course, part of the explanation can again lie in the lower number of observations when we break the data by sub-periods. The estimated treatment effects are biggest in magnitude during the 1970s, with 1.7 percentage points in the NNM, while in the 1980s they decrease to 0.9 and in the 1990s they lie close to 0.5 when significant (IPW).

In relative terms, the estimated ATET is highest during the 1980s (155%), followed by the 1970s (134%). Additionality, thus, was strongest before venture capital markets developed, pointing towards the important effects of public intervention in this context. The smaller estimated effect during the 1990s (58%) could be related to the large drop in the budgets of innovation agencies,

project applications, as well as the emergence of alternative private funding sources. While public funding collapsed in the mid-1990s, the amount of venture capital more than doubled between 1991 and 1995. The total volume in 1995 corresponded to 0.95% of GDP (Karaomerlioglu and Jacobsson, 2000). Correlations between innovation significance, applied amount, and ratios by decade are presented in table 15. When results are divided into the three time periods, no significant correlation with either applied amount nor coverage can be detected. This can most likely be accounted to the low number of observations in each period, dropping from 201 to 39-107. Nevertheless, the model fit is improved when considering time periods separately, exceeding the threshold of 0.2 which indicates a good fit (Hemmert et al., 2018).

C.2 Significance components

Apart from investigating changes across time, we have split the definition of high significance into three different components, market novelty, firm novelty, and the number of journal articles. Regarding the latter we distinguish whether innovations are mentioned in three or more articles. This is relevant for Q1 and Q3 only since Q2 does not consider variation in the level of significance. The results are presented in Tables 16 and 17 for Q1 and Q3, respectively.

For Q1 correlations are positive for all components of high significance. The amplitude is greatest for innovations declared to be a world novelty, amounting to a 54%. It should be noted that this is only half as strong a correlation as that of high significance.

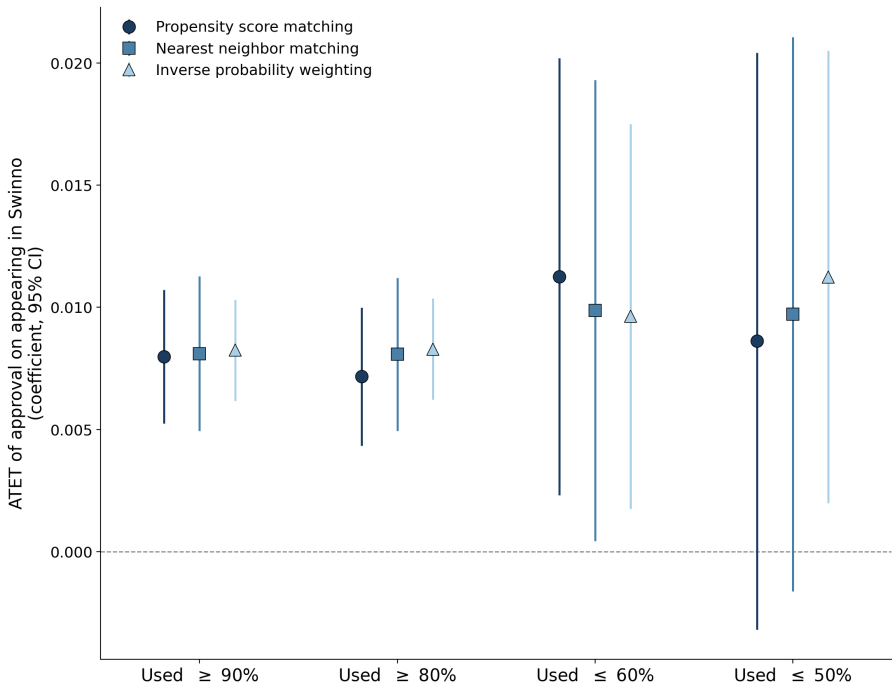
When conducting a separate analysis of significance components for Q3, neither of the three components is positively correlated with a higher amount of public funding. However, similar to the main regression results, the number of journal articles is negatively correlated with public funding coverage.

C.3 Use of the funds

For the STINS sample (1979-2001), we have information on the funds returned from the firms to the agency, i.e., the part not used. As mentioned above, most of the approved projects used their granted funds completely (the average is 96%). However, there is some variation that we can use to investigate whether the use of funds had an impact on the success of the projects in terms of developing a significant innovation (variation of Q2). If the actual use of the funds makes no difference, we may conclude that the approval of a project simply has an important "seal of approval" effect, which is similar for both groups. However, if the treatment effect is larger for projects where the funds were used, this would point towards the actual funding being important in addition to the prestige. We have run separate regressions using sub-samples of projects according to the extent to which they used the granted amounts. The results (figure 4) show that the significance of the treatment effects is weaker in the sub-samples of projects using less of the funds, with the confidence intervals sometimes crossing 0. This could point towards the actual use of the money being important, which would be consistent with the conclusions of Howell (2017); however, it should be noted that we have few observations in the low-use sub-samples, which affects the precision of the estimates. Therefore, we have to be cautious when interpreting this result. Projects that used less of the granted amounts might be projects which failed, for example cases of discontinued work after the development of a prototype that was not viable. Unfortunately, this is something we have no information on.³⁵

³⁵The full results can be found in table 4 in the Appendix. We have also run linear probability (OLS), probit, and logit regressions separately for these sub-samples. In all three, the coefficient on approval is positive and statistically significant at the 1% level in every sub-sample. The estimated effect of approval does not differ significantly across sub-samples: in the OLS specifications, the $\leq 60\%$ and $\leq 50\%$ sub-samples yield slightly larger coefficients, while in the probit and logit specifications they are slightly lower. These results are available upon request.

Figure 4: Treatment effect of approval by extent of funds usage



Source: authors' elaboration using Claude.

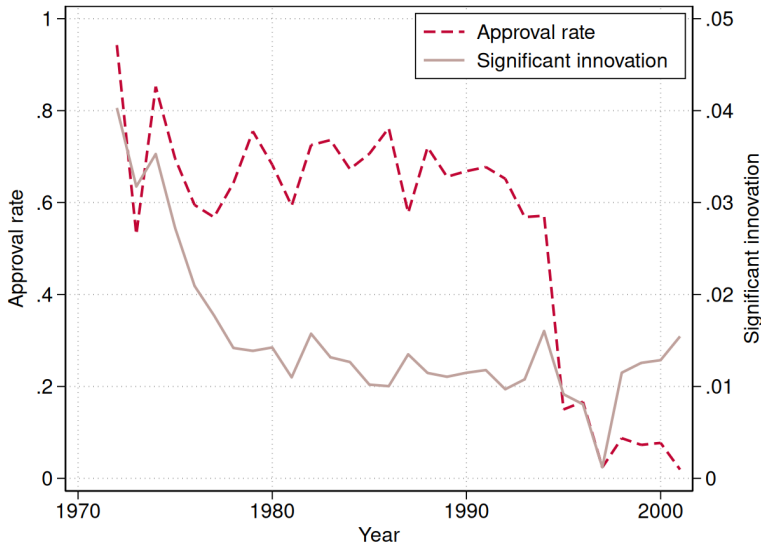
C.4 Exploiting approval rates

As was discussed in the data section, approval rates experienced significant variation through time (see Figure 5). It is shown that the percentage of projects connected to an innovation in Swinno was quite stable during the 1980s and early 1990s, before experiencing a drop in 1995 (57 to 15%) and a second drop in 1997 (17 to 2%) (blue line). These drops are related with an even more intense fall in the share of approved projects (red line). We exploit this variation in two ways: a) with an Instrumental Variable approach, where the yearly approval rate instruments approval; and b) with a Regression Discontinuity (RD) design, where we specifically look at the drop in approval rates in 1997.³⁶

Table 18 shows the estimated treatment effects with both approaches. The IV estimation yields positive results, consistent with our main analysis. The amplitude of the estimated effect is higher especially in comparison with the

³⁶The drop in approval rate is larger in 1995 than in 1997, but unfortunately we cannot use that year for the RD because the number of applied projects dropped as well, and many control variables present significant differences when comparing before and after (which is not the case in 1997).

Figure 5: Rates of significant innovation and project approval per year, 1972-2001



Source: combined Public Funding and Swinno Databases.

Notes: the projects are classified here according to the decision year, but this does not mean that project approval and appearance in Swinno happened at the same time. Normally, there is a delay between both, as discussed in the text, which is not seen in this figure.

subsample with confirmed size data. The RD analysis does not produce significant results. The effect is imprecisely estimated because the variable has generally low values and large variation, as the creation of a significant innovation is a rare outcome. Further, the sample containing only projects with a decision year after 1997 is relatively small having less than 3,300 observations. Finally, the economic downturn during the 1990s also affected innovation development negatively. The annual number of innovations in SWINNO during the 1990s is only around 70 compared to over 100 during previous decades.

C.5 Projects not granted because of budgetary reasons

In this section, we identify a sample of projects that were not granted because of budgetary reasons. That is, they were judged of sufficient quality, but the funds available to the innovation agency were not enough. This information is taken from a variable in the STINS database which contains more detailed information on the reasoning behind 6,306 rejected public funding projects. In this way, we can use a subsample of rejected projects that resembles even more closely the granted ones, in terms of quality. The analysis only covers years 1987-2001, since the subsample did not include any projects from earlier years. As can be seen in table 19, the coefficients tend to be positive but they are barely significant at the 10 percent level. This is because the number of observations, particularly for rejected projects, is very low compared to the original sample. We might take this as a weak confirmation of the additionality effects.

Table 13: Characteristics of innovative firms applying for public funding, by sub-period

	Logistic regression (odds-ratios)			
	(1) STU 1	(2) STU 2	(3) NUTEK	(4) All
Public	1.321 (0.622)	0.569 (0.169)	3.443** (0.025)	1.173 (0.562)
Past innovation	0.525*** (0.003)	0.622*** (0.005)	0.424*** (0.000)	0.523*** (0.000)
Past funding	3.195*** (0.000)	3.651*** (0.000)	4.280*** (0.000)	3.602*** (0.000)
Small (<50)	2.752*** (0.001)	2.941*** (0.000)	2.737*** (0.000)	2.750*** (0.000)
Large (>200)	0.963 (0.899)	0.562*** (0.007)	0.605* (0.096)	0.676*** (0.007)
Medium city	0.980 (0.930)	0.587*** (0.002)	0.943 (0.809)	0.762** (0.020)
Major city	1.626 (0.331)	1.480 (0.338)	0.631 (0.441)	1.133 (0.648)
Collaboration	0.691* (0.095)	0.755* (0.070)	0.802 (0.346)	0.736*** (0.005)
Patented	2.465*** (0.003)	1.784*** (0.009)	1.440 (0.129)	1.716*** (0.000)
High significance	2.882*** (0.000)	1.825*** (0.003)	1.720** (0.013)	2.076*** (0.000)
Construction	3.708 (0.271)	4.185* (0.057)	0.948 (0.950)	2.260* (0.084)
Health care	0.971 (0.985)	4.295 (0.105)	0.886 (0.906)	1.558 (0.445)
Information	4.378 (0.163)	3.698** (0.011)	1.338 (0.601)	2.695*** (0.004)
Transport and storage	14.324* (0.070)	1.008 (0.994)	1.000 (.)	1.641 (0.475)
Waste and water	3.447 (0.330)	2.799 (0.216)	1.000 (.)	1.946 (0.242)
Professional services	4.603 (0.274)	6.401* (0.098)	1.789 (0.489)	3.365** (0.034)
Energy	8.744* (0.075)	2.794 (0.132)	5.828** (0.032)	3.921*** (0.003)
Primary sector	1.000 (.)	1.000 (.)	1.000 (.)	3.143 (0.383)
Manufacturing	2.600 (0.405)	2.224 (0.198)	2.184 (0.258)	2.021* (0.089)
1975-1979	1.558** (0.044)	1.000 (.)		1.229 (0.273)
1980-1984		1.248 (0.419)		1.256 (0.201)
1985-1989		1.273 (0.412)		1.337 (0.126)
1990-1994		0.615 (0.330)	1.000 (.)	0.835 (0.394)
1995-2001			0.514*** (0.001)	0.456*** (0.000)
GDP growth	1.016 (0.629)	1.026 (0.609)	0.915** (0.035)	0.992 (0.698)
Constant	0.035*** (0.002)	0.060*** (0.000)	0.168*** (0.007)	0.085*** (0.000)
Observations	782	1152	714	2660
Pseudo R-sq	0.153	0.157	0.186	0.160

Notes: Baseline categories - Medium sized firm, medium and low significance, other sectors, first half of decade.

Table 14: Treatment effect of approval by sub-periods

Estimator	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
1970–1978						
PSM	.0189359	.0036695	5.16	0.000	.0117438	.026128
NNM	.0174723	.0063929	2.73	0.006	.0049425	.0300022
IPW	.0203828	.0029452	6.92	0.000	.0146103	.0261553
1979–1990						
PSM	.0095666	.0013511	7.08	0.000	.0069184	.0122147
NNM	.0093180	.0016354	5.70	0.000	.0061127	.0125232
IPW	.0090712	.0011849	7.66	0.000	.0067488	.0113936
1991–2001						
PSM	-.0012696	.0043570	-0.29	0.771	-.0098091	.00727
NNM	.0040474	.0031396	1.29	0.197	-.002106	.0102008
IPW	.0053273	.0021911	2.43	0.015	.0010329	.0096217

Source: author's calculations.

Notes: Number of obs = 11,972 in 1970–1978 (out of which 7,756 approved); 35,185 in 1979–1990 (out of which 24,002 approved); 14,880 in 1991 onwards (out of which 7,117 approved).

Table 15: Correlation between granted amount and innovation significance, by sub-periods

	Logistic regression (odds-ratios)			
	(1) STU 1	(2) STU 2	(3) NUTEK	(4) All
Log applied amount	-0.215 (0.729)	0.356 (0.199)	0.086 (0.815)	0.295* (0.066)
Coverage	-1.096 (0.646)	4.056 (0.487)	-5.113 (0.159)	-1.920* (0.082)
Collaboration	-15.495 (0.994)	1.688** (0.026)	0.939 (0.529)	1.068** (0.047)
Past innovation	1.052 (0.449)	1.118 (0.145)	-2.222 (0.152)	0.062 (0.898)
Past public funding	0.489 (0.755)	-0.601 (0.458)	0.914 (0.476)	-0.366 (0.451)
Public	16.748 (0.993)	-0.890 (0.391)	1.686 (0.439)	-0.231 (0.750)
Large (>200)	-1.553 (0.384)	0.041 (0.969)	15.135 (0.995)	-0.592 (0.391)
Small (<50)	0.896 (0.506)	0.905 (0.284)	15.451 (0.995)	0.489 (0.371)
Medium city	-0.518 (0.775)	0.023 (0.978)	2.105* (0.068)	0.479 (0.369)
Major city	0.000 (.)	0.599 (0.420)	-0.759 (0.588)	0.270 (0.613)
Construction	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Health care	0.000 (.)	2.721 (0.209)	0.000 (.)	1.385 (0.334)
Information	-1.640 (0.314)	0.156 (0.905)	-0.748 (0.721)	-0.485 (0.522)
Transport and storage	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Waste and water	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Professional services	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Energy	0.000 (.)	1.281 (0.575)	0.000 (.)	-0.771 (0.604)
Primary sector	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Other sectors	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
1975-1979	-1.284 (0.362)	0.000 (.)		-0.670 (0.432)
1980-1984		-0.400 (0.766)		0.247 (0.758)
1985-1989		-1.481 (0.330)		-0.859 (0.359)
1990-1994		0.671 (0.718)	0.000 (.)	0.480 (0.594)
1995-2001			-1.347 (0.188)	0.062 (0.942)
Constant	0.685 (0.828)	-6.372 (0.279)	-10.642 (0.997)	0.646 (0.637)
Observations	39	107	48	201
Pseudo R-sq	0.252	0.218	0.251	0.111

Table 16: Characteristics of innovative firms applying for public funding, 1970-2001 – Significance components

	Logistic regression (odds-ratios)			
	(1) Articles	(2) World nov.	(3) Firm nov.	(4) High sign.
Public	1.160 (0.587)	1.156 (0.594)	1.064 (0.821)	1.099 (0.732)
Past innovation	0.525*** (0.000)	0.511*** (0.000)	0.553*** (0.000)	0.516*** (0.000)
Past funding	3.580*** (0.000)	3.548*** (0.000)	3.533*** (0.000)	3.576*** (0.000)
Small (<50)	2.846*** (0.000)	2.705*** (0.000)	2.701*** (0.000)	2.559*** (0.000)
Large (>200)	0.683*** (0.008)	0.679*** (0.008)	0.684*** (0.008)	0.667*** (0.005)
Medium city	0.769** (0.024)	0.772** (0.027)	0.766** (0.022)	0.757** (0.018)
Major city	1.160 (0.585)	1.103 (0.719)	1.180 (0.544)	1.113 (0.697)
Collaboration	0.754*** (0.009)	0.760** (0.012)	0.743*** (0.006)	0.736*** (0.005)
Patented	1.759*** (0.000)	1.694*** (0.000)	1.761*** (0.000)	1.625*** (0.001)
Articles	1.766*** (0.000)			1.667*** (0.001)
World novelty		1.847*** (0.000)		1.693*** (0.000)
Firm novelty			1.443*** (0.000)	1.177 (0.119)
Construction	2.275* (0.082)	2.127 (0.116)	2.149 (0.110)	2.036 (0.139)
Health care	1.705 (0.358)	1.884 (0.269)	1.871 (0.275)	1.627 (0.401)
Information	2.828*** (0.003)	2.669*** (0.005)	2.799*** (0.003)	2.591*** (0.006)
Transport and storage	2.015 (0.298)	1.611 (0.491)	1.900 (0.347)	1.616 (0.488)
Waste and water	2.282 (0.148)	1.788 (0.305)	2.032 (0.217)	1.820 (0.292)
Professional services	3.361** (0.035)	3.267** (0.040)	3.491** (0.030)	3.241** (0.041)
Energy	3.969*** (0.003)	3.828*** (0.004)	3.776*** (0.004)	3.647*** (0.006)
Primary sector	2.986 (0.403)	3.445 (0.344)	2.891 (0.411)	3.600 (0.324)
Manufacturing	2.156* (0.063)	1.997* (0.095)	2.088* (0.075)	1.923 (0.115)
1975-1979	1.198 (0.334)	1.175 (0.391)	1.111 (0.573)	1.201 (0.331)
1980-1984	1.213 (0.277)	1.122 (0.516)	1.122 (0.518)	1.126 (0.505)
1985-1989	1.291 (0.176)	1.099 (0.619)	1.183 (0.374)	1.114 (0.573)
1990-1994	0.837 (0.395)	0.831 (0.377)	0.824 (0.355)	0.800 (0.292)
1995-2001	0.471*** (0.000)	0.463*** (0.000)	0.451*** (0.000)	0.453*** (0.000)
GDP growth	0.991 (0.670)	0.993 (0.762)	0.992 (0.695)	0.993 (0.755)
Constant	0.086*** (0.000)	0.088*** (0.000)	0.083*** (0.000)	0.086*** (0.000)
Observations	2660	2660	2660	2660
Pseudo R-sq	0.153	0.160	0.154	0.164

Notes Baseline categories - Medium sized firm, medium and low significance, other sectors, first half of decade.

Table 17: Correlation between granted amount and innovation significance - Significance components

	Logistic regression (odds-ratios)			
	Articles	World nov.	Firm nov.	High sign.
Log applied amount	1.061 (0.366)	1.018 (0.557)	1.010 (0.730)	1.044* (0.065)
Coverage	0.344** (0.033)	0.799 (0.322)	0.938 (0.766)	0.745* (0.096)
Collaboration	1.346 (0.218)	1.000 (1.000)	1.053 (0.621)	1.186** (0.047)
Past innovation	1.161 (0.422)	1.030 (0.725)	0.824** (0.017)	1.016 (0.807)
Past public funding	0.895 (0.577)	0.941 (0.496)	0.993 (0.937)	0.945 (0.423)
Public	1.056 (0.872)	1.299* (0.086)	1.267 (0.104)	0.961 (0.736)
Large (>200)	0.974 (0.921)	0.954 (0.687)	0.979 (0.852)	0.931 (0.438)
Small (<50)	0.977 (0.912)	1.097 (0.340)	1.240** (0.021)	1.071 (0.369)
Medium city	1.110 (0.633)	0.999 (0.989)	1.067 (0.493)	1.079 (0.327)
Major city	0.956 (0.839)	0.982 (0.857)	1.026 (0.785)	1.045 (0.573)
Construction	1.118 (0.831)	0.925 (0.741)	0.903 (0.649)	0.837 (0.334)
Health care	3.174* (0.085)	0.872 (0.652)	1.044 (0.882)	1.266 (0.321)
Information	1.187 (0.616)	0.807 (0.167)	0.752* (0.054)	0.932 (0.560)
Transport and storage	2.570 (0.425)	1.302 (0.623)	1.264 (0.647)	2.399** (0.038)
Waste and water	1.000 (.)	1.000 (.)	1.000 (.)	1.000 (.)
Professional services	0.918 (0.923)	1.045 (0.913)	0.467** (0.046)	0.828 (0.546)
Energy	1.079 (0.907)	0.882 (0.674)	0.845 (0.551)	0.907 (0.675)
Primary sector	0.708 (0.769)	0.539 (0.249)	0.464 (0.133)	0.812 (0.619)
Other sectors	0.592 (0.477)	0.753 (0.397)	0.609 (0.121)	0.719 (0.209)
1975-1979	1.082 (0.826)	0.934 (0.673)	1.097 (0.549)	0.914 (0.477)
1980-1984	1.665 (0.153)	1.090 (0.596)	1.208 (0.220)	1.028 (0.829)
1985-1989	1.152 (0.711)	1.198 (0.297)	1.191 (0.290)	0.894 (0.407)
1990-1994	1.956* (0.096)	1.143 (0.464)	1.355* (0.081)	1.062 (0.674)
1995-2001	1.470 (0.318)	1.029 (0.869)	1.207 (0.259)	0.996 (0.977)
Constant	7.453*** (0.001)	2.077** (0.010)	1.909** (0.017)	1.709** (0.016)
Observations	216	216	216	216
Pseudo R-sq				
R-sq	0.110	0.084	0.178	0.141

Table 18: Treatment effect of approval: IV and Regression Discontinuity approaches

Specification	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
<i>Instrumental Variables (approval rate as instrument)</i>						
Full sample (N=62,037)	.0149902	.0028566	5.25	0.000	.0093914	.020589
With size controls (N=42,797)	.0211254	.0034786	6.07	0.000	.0143075	.0279433
<i>Regression Discontinuity (1997 policy change, Wald estimate)</i>						
Wald estimate (N=3,281)	.0388302	.0499758	0.78	0.437	-.0591224	.1367829

Notes: The IV approach instruments approval with the mean approval rate by decision year; the second specification restricts the sample to observations with firm-size information and includes small/large firm controls. The RD approach exploits the 1997 policy change: the Wald estimate is calculated as the reduced-form effect of the post-1997 period on Swinno inclusion (coefficient = -.0062347, SE = .0079411) divided by the first-stage effect of the post-1997 period on approval (coefficient = -.1605640, SE = .0296906), with the standard error obtained via the delta method.

Table 19: Treatment effect of approval (ATET), with projects rejected because of budget

Estimator	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
PSM	.0063676	.0042418	1.50	0.133	-.0019461	.0146813
NNM	.0071459	.0042574	1.68	0.093	-.0011985	.0154903
IPW	.0055028	.0033023	1.67	0.096	-.0009697	.0119753

Notes: Number of obs = 15,377; out of which 14,134 treated and 1,243 controls. We run the models using lustrum instead of decision year to reduce the number of variables.

Source: author's calculations.

Appendix D Additional regressions for Q1

Table 20: Characteristics of innovative firms applying for public funding, 1970–2001 – Logistic regression (conventional standard errors)

	Logistic regression (odds-ratios)			
	(1) Firm	(2) Innovation	(3) Sector	(4) Time
Public	1.084 (0.754)	1.182 (0.534)	1.133 (0.645)	1.173 (0.562)
Past innovation	0.498*** (0.000)	0.524*** (0.000)	0.524*** (0.000)	0.523*** (0.000)
Past funding	3.324*** (0.000)	3.504*** (0.000)	3.545*** (0.000)	3.602*** (0.000)
Small (<50)	2.972*** (0.000)	2.841*** (0.000)	2.814*** (0.000)	2.750*** (0.000)
Large (>200)	0.719** (0.017)	0.718** (0.019)	0.714** (0.017)	0.676*** (0.007)
Medium city	0.809* (0.059)	0.776** (0.026)	0.787** (0.037)	0.762** (0.020)
Major city	1.140 (0.620)	1.168 (0.564)	1.235 (0.436)	1.133 (0.648)
Collaboration		0.758*** (0.009)	0.746*** (0.006)	0.736*** (0.005)
Patented		1.454*** (0.005)	1.474*** (0.004)	1.716*** (0.000)
High significance		1.814*** (0.000)	1.817*** (0.000)	2.076*** (0.000)
Construction			2.210* (0.087)	2.260* (0.084)
Health care			1.585 (0.419)	1.558 (0.445)
Information			2.847*** (0.002)	2.695*** (0.004)
Transport and storage			1.875 (0.345)	1.641 (0.475)
Waste and water			2.322 (0.130)	1.946 (0.242)
Professional services			2.457 (0.114)	3.365** (0.034)
Energy			3.985*** (0.002)	3.921*** (0.003)
Primary sector			3.239 (0.358)	3.143 (0.383)
Manufacturing			2.015* (0.083)	2.021* (0.089)
1975–1979				1.229 (0.273)
1980–1984				1.256 (0.201)
1985–1989				1.337 (0.126)
1990–1994				0.835 (0.394)
1995–2001				0.456*** (0.000)
GDP growth				0.992 (0.698)
Constant	0.242*** (0.000)	0.218*** (0.000)	0.080*** (0.000)	0.085*** (0.000)
Observations	2660	2660	2660	2660
Pseudo R-sq	0.124	0.136	0.141	0.160

Notes Baseline categories – Medium sized firm, medium and low significance, other sector, 1970–1974.

Table 21: Characteristics of innovative firms applying for public funding, 1970-2001 - Probit regression

	Probit regression			
	(1) Firm	(2) Innovation	(3) Sector	(4) Time
Public	1.031 (0.843)	1.079 (0.628)	1.058 (0.722)	1.097 (0.555)
Past innovation	0.663*** (0.000)	0.684*** (0.000)	0.683*** (0.000)	0.681*** (0.000)
Past funding	1.985*** (0.000)	2.055*** (0.000)	2.065*** (0.000)	2.094*** (0.000)
Small (<50)	1.953*** (0.000)	1.889*** (0.000)	1.878*** (0.000)	1.845*** (0.000)
Large (>200)	0.836** (0.029)	0.832** (0.027)	0.831** (0.026)	0.803*** (0.010)
Medium city	0.886* (0.069)	0.863** (0.029)	0.871** (0.041)	0.851** (0.019)
Major city	1.114 (0.485)	1.134 (0.419)	1.167 (0.323)	1.089 (0.586)
Collaboration		0.844*** (0.007)	0.836*** (0.005)	0.835*** (0.005)
Patented		1.258*** (0.004)	1.266*** (0.004)	1.389*** (0.000)
High significance		1.429*** (0.000)	1.430*** (0.000)	1.532*** (0.000)
Construction			1.567* (0.094)	1.571* (0.095)
Health care			1.266 (0.477)	1.249 (0.508)
Information			1.842*** (0.001)	1.758*** (0.003)
Transport and storage			1.422 (0.368)	1.303 (0.512)
Waste and water			1.601 (0.152)	1.416 (0.297)
Professional services			1.691 (0.111)	1.975** (0.041)
Energy			2.219*** (0.003)	2.164*** (0.004)
Primary sector			2.026 (0.363)	1.999 (0.399)
Manufacturing			1.531* (0.061)	1.516* (0.070)
GDP growth				0.996 (0.748)
1975-1979				1.100 (0.383)
1980-1984				1.122 (0.267)
1985-1989				1.162 (0.176)
1990-1994				0.879 (0.298)
1995-2001				0.620*** (0.000)
Constant	0.430*** (0.000)	0.404*** (0.000)	0.226*** (0.000)	0.243*** (0.000)
Observations	2660	2660	2660	2660
Pseudo R-sq	0.122	0.134	0.139	0.158

Notes Baseline categories - Medium sized firm, medium and low significance, other sectors, 1970-1974.

Table 22: Characteristics of innovative firms applying for public funding, 1970-2001 - clustered standard errors on firm level

	Logistic regression (odds-ratios)			
	(1) Firm	(2) Innovation	(3) Sector	(4) Time
Public	1.084 (0.838)	1.182 (0.675)	1.133 (0.765)	1.173 (0.724)
Past innovation	0.498*** (0.000)	0.524*** (0.000)	0.524*** (0.000)	0.523*** (0.000)
Past funding	3.324*** (0.000)	3.504*** (0.000)	3.545*** (0.000)	3.602*** (0.000)
Small (<50)	2.972*** (0.000)	2.841*** (0.000)	2.814*** (0.000)	2.750*** (0.000)
Large (>200)	0.719 (0.127)	0.718 (0.131)	0.714 (0.129)	0.676* (0.085)
Medium city	0.809 (0.269)	0.776 (0.195)	0.787 (0.228)	0.762 (0.167)
Major city	1.140 (0.748)	1.168 (0.711)	1.235 (0.636)	1.133 (0.792)
Collaboration		0.758* (0.082)	0.746* (0.069)	0.736* (0.057)
Patented		1.454** (0.043)	1.474** (0.036)	1.716*** (0.004)
High significance		1.814*** (0.000)	1.817*** (0.000)	2.076*** (0.000)
Construction			2.210 (0.107)	2.260 (0.116)
Health care			1.585 (0.515)	1.558 (0.518)
Information			2.847*** (0.007)	2.695** (0.016)
Transport and storage			1.875 (0.377)	1.641 (0.495)
Waste and water			2.322 (0.191)	1.946 (0.310)
Professional services			2.457 (0.216)	3.365* (0.099)
Energy			3.985*** (0.008)	3.921** (0.017)
Primary sector			3.239 (0.424)	3.143 (0.352)
Manufacturing			2.015 (0.150)	2.021 (0.172)
GDP growth				0.992 (0.778)
1975-1979				1.229 (0.398)
1980-1984				1.256 (0.342)
1985-1989				1.337 (0.298)
1990-1994				0.835 (0.504)
1995-2001				0.456*** (0.001)
Constant	0.242*** (0.000)	0.218*** (0.000)	0.080*** (0.000)	0.085*** (0.000)
Observations	2660	2660	2660	2660
Pseudo R-sq	0.124	0.136	0.141	0.160

Notes Baseline categories - Medium sized firm, medium and low significance, other sectors, 1970-1974.

Appendix E Additional regressions for Q2

In this appendix we show the results of OLS, probit, and logit regressions of *Swinno* on *Approval* and our control variables. They seek to illustrate simpler approaches to the question in our Q2 section, namely whether getting public funding leads to a higher probability of developing a top innovation. In all these regressions the *Approval* variable is statistically significant and with a positive sign, which reinforces the robustness of our results. The regressions shown here, however, do not control for selection (for the fact that approval is not random). Secondly, we add the full results of the robustness analysis regarding the use of the funds (table 24).

Table 23: Summary of Regression Results (Q2): OLS, Probit, and Logit

Variable	OLS	Probit	Logit (Odds Ratio)
Approval	0.0118*** (0.0011)	0.4349*** (0.0366)	2.9465*** (0.2774)
Applied amount (log)	0.0029*** (0.0002)	0.1456*** (0.0101)	1.4271*** (0.0338)
Past public funding	0.0073*** (0.0012)	0.1530*** (0.0329)	1.3969*** (0.1109)
Public ownership	-0.0258*** (0.0012)	-1.0125*** (0.0511)	0.0684*** (0.0103)
Major town	-0.0044*** (0.0013)	-0.1390*** (0.0397)	0.7054*** (0.0687)
Medium town	0.0043*** (0.0014)	0.0963** (0.0397)	1.2744** (0.1192)
<i>Sectors</i>			
Manufacturing	0.0045*** (0.0016)	0.1168** (0.0463)	1.3192** (0.1479)
Professional services	-0.0001 (0.0018)	-0.0335 (0.0567)	0.9254 (0.1300)
Information & Communication	0.0011 (0.0013)	0.0177 (0.0407)	1.0719 (0.1068)
Energy	0.0017 (0.0020)	0.0226 (0.0588)	1.0517 (0.1496)
Construction	0.0008 (0.0026)	0.0031 (0.0747)	0.9797 (0.1781)
Health	-0.0016 (0.0028)	-0.1105 (0.0997)	0.7911 (0.1949)
Transport	0.0061 (0.0040)	0.1031 (0.1068)	1.3948 (0.3384)
Water & Waste	0.0118*** (0.0040)	0.2328** (0.1008)	1.8197*** (0.4110)
Agriculture, Forestry, & Fishing	-0.0016 (0.0048)	-0.1020 (0.1688)	0.7750 (0.3270)
Constant	0.0358*** (0.0043)	-2.0079*** (0.0964)	0.0208*** (0.0045)
Observations	62,037	62,037	62,037
R-squared / Pseudo R-squared	0.0148	0.1163	0.1171
Year FE	Yes	Yes	Yes

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 24: Treatment effect of approval by extent of funds usage

Estimator	Coefficient	Robust std. err.	z	P> z	[95% conf. interval]	
Used ≥90% of granted funds						
PSM	.0079828	.0013964	5.72	0.000	.0052458	.0107197
NNM	.0081057	.0016121	5.03	0.000	.0049459	.0112654
IPW	.0082494	.0010541	7.83	0.000	.0061835	.0103153
Used ≥80% of granted funds						
PSM	.0071634	.0014433	4.96	0.000	.0043347	.0099922
NNM	.0080789	.0015963	5.06	0.000	.0049502	.0112075
IPW	.0082911	.0010542	7.87	0.000	.0062249	.0103572
Used ≤60% of granted funds						
PSM	.0112594	.0045633	2.47	0.014	.0023155	.0202032
NNM	.0098693	.0048134	2.05	0.040	.0004352	.0193035
IPW	.0096272	.0040177	2.40	0.017	.0017527	.0175017
Used ≤50% of granted funds						
PSM	.0086175	.006021	1.43	0.152	-.0031833	.0204184
NNM	.0097176	.005787	1.68	0.093	-.0016248	.02106
IPW	.0112418	.0047221	2.38	0.017	.0019866	.0204971

Notes: Number of obs = 47,082 for projects using $\geq 90\%$ of granted funds (out of which 28,256 with positive approval); 47,774 for projects using $\geq 80\%$ of granted funds (out of which 28,948 with positive approval); 19,771 for projects using $\leq 60\%$ of granted funds (out of which 1,199 with positive approval); 19,481 for projects using $\leq 50\%$ of granted funds (out of which out of which 909 with positive approval). In the last two sub-samples, decision year 2001 was excluded, since it was a perfect predictor.

Source: author's calculations.

Appendix F Alternative estimation for Q3

Since significance has three different outcomes, an ordered logistic regression model is used as an alternative to the simple logit model presented in equation 4.³⁷ This model presented in equation 5 predicts the probability that an innovation i is equal to or below a certain threshold m of innovation quality, based on a set of covariates X_{it} .

$$\begin{aligned} \text{logit}(P(Q_i \leq m \mid X_{it})) &= \log \left(\frac{P(Q_i \leq m \mid X_{it})}{P(Q_i > m \mid X_{it})} \right), \quad (1 \leq m < M) \\ &= \alpha_m - \beta_1 \text{Amount}_i - \beta_2 \text{Ratio}_i - \beta_3 C_i - \beta_4 [\sum_{t_z < t}^{t-1} \text{Approval}_{j,t_z} \neq 0] \\ &\quad - \beta_5 [\sum_{t_z < t}^{t-1} \text{Innovation}_{j,t_z} \neq 0] - \beta_6 \text{Public}_j - \beta_7 \text{Large}_j - \beta_8 \text{Small}_j \\ &\quad - \beta_9 \text{Medium}_j - \beta_{10} \text{Major}_j - \delta_i - \theta_t - \varepsilon. \end{aligned} \quad (5)$$

The results are presented in table 25. The results are very close to those of the main text. Under this model specification the correlation between higher applied amount and innovation significance disappears. Nonetheless, collaborative innovation continues to be positively associated with innovation quality, while past access to public funding indicates lower innovation quality. The latter might be concerning for policy makers aiming to develop primarily highly significant rather than incremental innovations, since firms repeatedly applying for public funding are associated with generating innovations with a low degree of novelty.

Nonetheless, it should be considered that firms with past access to public funding are primarily large conglomerates like ABB, Saab, and Volvo, which are traditionally most likely to optimize their production processes rather than developing new products (Dahlstrand and Cetindamar, 2000; Asheim and Moodysson, 2017). Moreover, this might simply be related to structural cycles in economic development. Based on the model of structural cycles by Schön (2010), economic activity undergoes regularly shifts between (1) phases where new technologies are introduced and (2) existing ones are optimized. Schön classifies both the early 1970s and 1990s, and thus half the research period, as the latter type where existing technologies are improved.

³⁷For further details on ordered logistic regression models, see Fullerton (2009).

Table 25: Correlation between granted amount and innovation quality - Alternative regression model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log applied amount	1.121 (0.116)								1.135 (0.135)
Coverage		0.724 (0.105)							0.789 (0.274)
Collaboration			1.437 (0.146)						1.831* (0.075)
Past innovation				1.055 (0.807)					1.005 (0.986)
Past public funding					0.659* (0.089)				0.594* (0.060)
Public						1.100 (0.789)			0.900 (0.825)
Large (>200)							1.267 (0.540)		1.275 (0.572)
Small (<50)							1.995** (0.044)		2.050** (0.048)
Medium city								0.912 (0.790)	0.809 (0.570)
Major city								1.376 (0.289)	1.419 (0.289)
1975									0.971 (0.947)
1980									1.132 (0.787)
1985									1.594 (0.335)
1990									1.640 (0.316)
1995									1.051 (0.966)
Chemistry									0.608 (0.372)
Energy									1.729 (0.252)
Environment									2.079 (0.149)
Equipment									1.217 (0.696)
Food									1.572 (0.504)
Information									1.586 (0.257)
Material									0.847 (0.734)
Medicine									1.066 (0.888)
Natural resource									2.779 (0.416)
Product dev.									0.819 (0.518)
Production									1.195 (0.742)
Transport									0.806 (0.639)
Cut 1	0.052*** (0.000)	0.037*** (0.000)	0.055*** (0.000)	0.052*** (0.000)	0.037*** (0.000)	0.051*** (0.000)	0.080*** (0.000)	0.052*** (0.000)	0.061*** (0.000)
Cut 2	3.954*** (0.000)	2.794*** (0.000)	4.078*** (0.000)	3.825*** (0.000)	2.742*** (0.000)	3.754*** (0.000)	6.150*** (0.000)	3.866*** (0.000)	5.807*** (0.008)
Observations	412	412	434	434	434	434	434	434	412
Pseudo R-sq	0.004	0.004	0.003	0.000	0.005	0.000	0.010	0.002	0.045

Source: authors' calculations.

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Shaping innovation

Innovation and technological progress have been identified as key drivers of long-term economic growth. However, not all innovation is supporting sustained economic growth or addressing societal concerns such as climate change. Against this backdrop, researchers advocate for active government intervention in shaping technological development, a role that governments have increasingly assumed in recent decades. Yet, it remains unclear where exactly public funds are channeled, and whether this is in line with wider policy objectives.

This thesis offers empirical evidence on the allocation of public funding in Sweden between 1970-2021. To this end, a comprehensive database over public innovation funding is created, where individual public funding projects are directly linked to innovation outputs. The database has been used to investigate the quantitative dimension, direction, network additionality, and output additionality of public funding. Sweden is selected as the research subject, since it was among the first countries to actively promote applied research, ranks among the most innovative countries today, and is considered a pioneer in sustainable development.

The thesis highlights the importance of public support for innovation development. It shows that public funding is associated with types of innovation projects that are typically less likely to receive private funding, particularly innovations developed by small firms, radical innovation, and green innovation. Innovations involving innovation agencies are more likely to bring together diverse sets of collaborators, which in turn are associated with the development of radical innovations. Finally, public funding shows signs of output additionality, as approved public funding projects are nearly twice as likely to generate significant innovation outputs.