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How R&D subsidies alter firm activities and behaviour

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ABSTRACT
Public research and development (R&D) subsidies are often used to increase firms' R&D investments and innovation efforts and to spur firm-level additionalities, such as increased R&D inputs and innovation outcomes. However, relatively little is known about how such firm-level additionalities develop and interrelate over time. This study examines 15 cases of successful R&D projects to explore how additionalities from public subsidies are developed over time. We develop a process model outlining how different types of additionalities from public R&D subsidies develop and interrelate at the beginning of, during and after a project for science- and engineering-based firms. For science-based firms, public R&D subsidies appear to strengthen innovation and knowledge development after projects are completed and to increase firms' strategic R&D orientation. For engineering-based firms, subsidies leverage internal credibility and collaboration, which leads to increased R&D activities, mainly during projects. Given these results, we provide guidance for policy and practice regarding how different types of firms benefit from subsidised R&D projects both during and after the project period.

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Additionality; firm behaviour; public R&D subsidies; innovation; R&D projects; R&D collaboration

Introduction

Public R&D subsidies are a key policy instrument aiming to increase firms' R&D activities and innovativeness (Aerts & Schmidt, 2008; Ciabuschi et al., 2020; Kochenkova et al., 2016; Torregrosa-Hetland et al., 2019). A key question for any R&D subsidy is related to how the results differ from a situation without the subsidy, which is referred to as the additionality of the subsidy. Studies have documented that public R&D subsidies can lead to different types of additionalities, such as higher R&D inputs (Dimos & Pugh, 2016; Hud & Hussinger, 2015) and improved innovation outcomes (Czarnitzki & Hussinger, 2018; Dimos & Pugh, 2016). However, specific types of additionalities are often studied in isolation (Dimos & Pugh, 2016), and there is limited understanding of *how* different types of additionalities develop (Clarysse et al., 2009; Kochenkova et al., 2016) and interrelate over time (Dimos & Pugh, 2016; Falk, 2007; Knockaert et al., 2014).

A better processual understanding of how R&D subsidies lead to the development of additionalities at the firm level is crucial for designing effective policy interventions. Prior empirical research provides mixed findings regarding the existence of additionalities (Dimos & Pugh, 2016), in which firm characteristics have been pointed to as a possible

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explanation for the diverging findings (Aerts & Schmidt, 2008; Dimos & Pugh, 2016). There are also indications that receiving an R&D subsidy can lead to important indirect additionalities that are more difficult to assess (Chapman & Hewitt-Dundas, 2018; Georghiou, 2007), such as increased R&D activities, collaboration (Falk, 2007; Gök & Edler, 2012), and learning, which may influence firms' long-term R&D activities (Clarysse et al., 2009; Dimos & Pugh, 2016). Hence, it seems clear that R&D subsidies are associated with different types of addtionalities, but less is known about the processual aspects, such as the timing, interrelationships, and firm-specific additionalities.

This paper responds to calls for longitudinal, qualitative studies on the interrelations between different types of additionalities (Dimos & Pugh, 2016; Falk, 2007; Knockaert et al., 2014). By studying how two types of firms – science-based and engineering-based firms (Autio, 1997) – develop additionalities from R&D subsidies, we seek a better conceptual understanding to guide firms and policymakers. Public R&D subsidies typically not only provide cash but also require specific conditions to be met, such as collaboration between firms and academic partners (Szücs, 2018), which is often conducted through subsidised R&D projects (Davenport et al., 1998). Hence, we address the following research questions: (1) *How do science- and engineering-based firms develop additionalities from subsidised R&D projects*, and (2) *how do these additionalities interrelate over time?*

To answer these questions, we conducted a qualitative, longitudinal study (Dimos & Pugh, 2016; Falk, 2007; Knockaert et al., 2014) of 15 subsidised R&D projects conducted by Norwegian firms in collaboration with academic partners that generated successful innovation outcomes. Using archival data and interviewing several key project members from each case some years after the completion of each project, we obtained a rich account of how the different firm additionalities from these projects materialised and interrelated over time.

Our study makes three contributions to the literature. First, our key contribution is linked to *how* different additionalities from subsidised R&D projects develop and interrelate in a process over time (Clarysse et al., 2009; Dimos & Pugh, 2016; Falk, 2007; Kochenkova et al., 2016). We find that additionalities from an R&D project develop through a process in which sub-dimensions of additionalities develop and interrelate at different stages of the project (i.e., at the start of, during, and after the project). We develop a process model illustrating how firms develop different types of additionalities. As such, we add to the discussion about the role of R&D subsidies in the innovation policy mix (Dumont, 2017; Radicic & Pugh, 2017) by emphasising how these subsidies can influence firm behaviour and outcomes on several dimensions and timescales.

Second, we provide novel insights into the role of firm characteristics (Aerts & Schmidt, 2008; Dimos & Pugh, 2016) by identifying how the additionalities of public R&D subsidies are developed for two distinct types of firms. For *science-based firms*, subsidies increase innovation and knowledge and enhance these firms' strategic and long-term R&D orientation. For *engineering-based firms*, subsidies facilitate internal credibility and collaboration within these firms, in turn leading to more R&D activities.

Third, we provide more detailed knowledge on the development of different additionalities from public R&D subsidies (Clarysse et al., 2009; Kochenkova et al., 2016). For behavioural additionality, we add the new sub-dimension of *changes in organisational goals* and confirm and extend the sub-dimension of *increased R&D activities* from prior research (Hsu et al., 2009). For output additionality, we confirm three sub-dimensions from the existing research – *innovation* (Clarysse et al., 2009), *knowledge development* (Hsu et al., 2009), and *firm performance* (Ciabuschi et al., 2020; Georghiou, 2002) – and elaborate on how these dimensions are related.

Additionalities from publicly subsidised R&D projects in firms

Public subsidies of private R&D are often grounded in neoclassical theories asserting that market failures cause firms to underinvest in innovation (Arrow, 1962; Nelson, 1959). The role of public policy is therefore assumed to remedy this negative externality, and a variety of policy instruments have been established to promote firm innovation through R&D subsidies (Clarysse et al., 2009; Dimos & Pugh, 2016; Marino et al., 2016). This support can be indirect, such as through tax incentives (Bodas Freitas et al., 2017), or more direct, such as through publicly supported R&D programmes (Davenport et al., 1998). Firms often use several support initiatives in combination, providing a policy mix of public support (Lanahan & Feldman, 2015).

Publicly supported R&D programmes are increasingly used as government tools to boost innovation and competitiveness by modifying firm behaviour and capabilities, thus producing additionalities (Davenport et al., 1998; Georghiou, 2002; Yi et al., 2021). Additionality relates to increasing desired firm outcomes or activities that would not have been realised without the support, and has been defined as 'the change in firm-financed R&D spending, company behaviour, or performance that would not have occurred without the public intervention' (Georghiou & Clarysse, 2006, p. 428). Even if a highly profitable project has been supported by a public subsidy, the support is not *additional* unless the project's profit has been increased or other effects have emerged as a result of the public subsidy.

The literature mainly distinguishes between three types of additionalities – input, output, and behavioural additionalities – which are all relevant when examining the effects of R&D programmes at the project level (Clarysse et al., 2009). However, the distinctions between these additionalities are not always clear cut (Cerulli et al., 2016; Clarysse et al., 2009), and different terms are often used to describe them.

Input additionality

Input additionality is the most straightforward dimension to measure (Cerulli et al., 2016) and the most frequently used (Cerulli et al., 2016; Dimos & Pugh, 2016). Input additionality is often used to assess whether firms have increased their R&D investments because of public R&D support (Clarysse et al., 2009; Georghiou et al., 2004). A programme is considered effective if a firm makes additional R&D investments due to having received a subsidy (Georghiou, 2002) and is considered inefficient if the same investments would have been made without the public support. A situation in which a subsidy replaces firm investments is also known as the crowding-out effect (Clarysse et al., 2009). After reviewing more than 70 empirical studies, Zúñiga-Vicente et al. (2014) conclude that almost all studies find positive effects of R&D subsidies on firm-level R&D investments. Further, based on a meta-regression analysis, Dimos and Pugh (2016) reject the problem of public subsidies crowding out firm investments.

Output additionality

Output additionality concerns the outputs that would not have been achieved without a subsidy (Georghiou, 2002) – in other words, the extent to which R&D results are different than they would have been without an R&D subsidy (Hsu et al., 2009). Positive innovation outputs from R&D subsidies have been documented by measuring patenting and R&D applications (e.g., Howell, 2017; Wang et al., 2017). Moreover, studies have shown that firms that have received public R&D subsidies are more likely to increase their financial performance (Howell, 2017; Zhao & Ziedonis, 2012) and growth (Aguiar & Gagnepain, 2017). Output additionality can also encompass firm-level learning effects from technology diffusion, knowledge exchange, and spill over (Autio et al., 2008; Hsu et al., 2009), which can be related to knowledge development (Hsu et al., 2009).

Behavioural additionality

Behavioural additionality focuses on firms' ability to change their behaviour (Buisseret et al., 1995; Clarysse et al., 2009) through learning effects from conducting publicly subsidised R&D projects. Behavioural additionality can be defined as a change in firm behaviour that arises from government intervention (Davenport et al., 1998). This change can occur at either the strategic level, such as when firms move into new areas or activities, or through the acquisition of new competences (Buisseret et al., 1995; Davenport et al., 1998). In contrast to input and output additionalities, behavioural additionalities are inherently intangible (Falk, 2007). Behavioural additionalities can be measured as changes in the way firms manage their R&D activities (Buisseret et al., 1995; Davenport et al., 1998), such as by starting new collaborations with universities (Bronzini & Piselli, 2016; Cerulli et al., 2016) and corporate partners (Bianchi et al., 2019). Hence, behavioural additionalities can imply that managers give priority to R&D activities and that firms have built overall faith in the strategic value of R&D investments (Chapman & Hewitt-Dundas, 2018; Davenport et al., 1998). Behavioural additionalities are typically the long-term effects from a subsidy (George et al., 2002). Hence, behavioural additionalities serve as potential precursors for input and output additionalities over time (Cerulli et al., 2016).

Interrelations between input, output, and behavioural additionalities

A few studies have examined how various additionalities interrelate. Clarysse et al. (2009) find that an input additionality correlates with a behavioural additionality, meaning that firms that alter their management methods tend to continue to emphasise R&D and research personnel. Davenport et al. (1998) examine the effects of company R&D support and find that a behavioural additionality is likely to strengthen a policy's ability to influence the creation of an output additionality. However, prior research on additionalities from public R&D subsidies has mainly studied input, output, and behavioural additionalities separately (Cerulli et al., 2016) and has stressed the need for more studies investigating the relationships between them (Dimos & Pugh, 2016; Falk, 2007).

Firm heterogeneity and additionalities

Several studies have indicated that the additionalities from R&D subsidies might differ depending on firm characteristics (Dimos & Pugh, 2016; Herrera & Sánchez-González, 2013; Wanzenböck et al., 2013), such as firm size (number of employees) and sectoral affiliation. Bronzini and Piselli (2016) find that R&D subsidy programmes have a positive impact on subsidised firms' number of patent applications, with the effect being significantly greater for smaller firms than for larger firms. A recent study distinguishing between service and manufacturing firms and between knowledge-intensive and non-knowledge-intensive firms finds stronger performance effects from subsidies for firms in R&D-intensive industries (Vanino et al., 2019). Moreover, Wanzenböck et al. (2013) find that small, young, and technologically specialised firms are more likely than R&D-intensive firms to realise behavioural additionalities from R&D subsidies.

Hence, we study both science-based and engineering-based firms (Autio, 1997) because they usually have different motivations and behaviours related to technology development and the pursuit of technological opportunities. Science-based firms mainly develop core knowledge and new technologies based on scientific breakthroughs (Chidamber et al., 1994). Engineering-based firms mainly exploit market opportunities by developing application-specific technologies and by expanding the usage of such applications (Autio, 1997). Moreover, engineering-based firms mainly develop improved technologies and processes to solve specific practical challenges, such as those related to plant engineering and industrial machinery (Asheim & Coenen, 2005).

Science-based firms tend to be more R&D intensive and interact with academic environments from which they absorb knowledge, while engineering-based firms are less R&D intensive and more connected to industrial settings (Autio, 1997). Compared to engineering-based firms, science-based firms more often have social relationships with, shared understandings with, and technological knowledge similar to that of R&D institutions (Steinmo & Rasmussen, 2016). One example is firms in the biotechnology industry, which depends more on public science for basic research compared to other industries (McMillan et al., 2000).

In sum, studies have contributed with insights on additionality effects from public R&D subsidies, but there is still a lack of a processual understanding of *how* additionalities develop (Clarysse et al., 2009; Kochenkova et al., 2016) and interrelate over time (Dimos & Pugh, 2016; Falk, 2007; Knockaert et al., 2014).

Methodology

Research design

We use a qualitative case-study approach to investigate how additionalities of publicly subsidised R&D projects are developed (Eisenhardt, 1989). Our longitudinal, multiple-case-study design allows us to build theory (Yin, 2014) on how firm-level additionalities develop during and after R&D projects, and it facilitates a rich and contextualised understanding of a phenomenon that has scarcely been addressed (Eisenhardt, 1989). Because additionalities are difficult to operationalise and measure and are concealed by timing issues (Clarysse et al., 2009), our study provides a unique opportunity to capture the in-depth nuances of how firms develop additionalities, both those that are easier to measure (e.g., investments or products) and those that are more challenging to measure (e.g., goal changes or knowledge development).

Case selection

Prior research on additionality from R&D subsidies has often relied on cross-sectional survey data, such as the Community Innovation Survey (e.g., Aerts & Schmidt, 2008; Cerulli et al., 2016) and surveys of selected firms (e.g., Clarysse et al., 2009; Falk, 2007) or R&D programmes (e.g., Autio et al., 2008; Bronzini & Piselli, 2016). However, while R&D activities are typically conducted as projects, most prior studies lack information at the project level (Davenport et al., 1998).

Our cases are therefore drawn from a public support scheme – the user-driven innovation projects (BIP) scheme – which supports high-potential innovation projects in Norwegian industries. BIP is operated by the Research Council of Norway with the aim of increasing R&D and innovation activities in firms. While firms may receive a policy mix of R&D support (Dumont, 2017), the specific projects examined by this study were solely supported by BIP. BIP gives subsidies as R&D grants (20–40%), and the remaining project costs (60–80%) are financed by the firms themselves (cash or in-kind). BIP is one of the largest activities within the Research Council, constituting 16% of total grants in 2009 and about 12% in 2019. In total, 2,924 BIP grants were applied for between 2000 and 2007, and 45.8% received support (Bræin et al., 2009). Firms set the premises for their projects, which are designed and conducted according to project applications. While firms apply for grants and act as contract partners with the Research Council, all projects include R&D organisations (universities and/or public research organisations) and sometimes other firms as partners.

We aimed at studying projects that would provide extensive examples of additionality development rather than providing a representative sample. Hence, we selected cases from a population of 709 projects that were supported by BIP in the period from 1996 to 2005. To capture how additionalities develop over a long time period, we made an ex-post selection of 15 top-performing projects, measured as the contribution to profit reported by the lead firms four years after the projects ended. The projects were managed by firms of various sizes, came from different industries, and developed different types of innovations, thus providing contextual variety (Yin, 1989). The total budgets of the individual projects ranged from 1 to 60 million NOK, with the largest firms tending to have the largest budgets. Table 1 shows the firm characteristics for our sample and classifies each firm as either science-based or engineering-based according to definitions from the literature.

Data collection

The data include initial project descriptions, final reports, and assessments conducted by BIP as well as survey responses from each firm at the start of the project, at the end of the project, and four years after the project period ended. To obtain an in-depth

Table 1. Categorisation of the science-based and engineering-based case firms.

Case	Type of firm (size* and industry)	Total budget (million NOK)**	Exploitation of technology (Autio, 1997)	Technology development (Autio, 1997)	R&D ties (Arrow, 1994; Asheim & Coenen, 2005)	R&D orientation (Autio, 1997)
1	Science-based (Small biotech start-up)	1–10	Scientific breakthrough	New technology	Collaborations with several universities and R&D organisations	R&D is a key part of the firm
2	Science-based (Micro ICT start-up)	1–10	Scientific breakthrough	New technology	Employs several researchers; close relationships with academic researchers	R&D is the main activity of the firm
3	Science-based (Small science start-up)	1–10	Patent testing	New technology	Established by researchers and has a connection with one research organisation in particular	R&D is the main activity of the firm
4	Science-based (Micro biotech start-up)	1–10	Scientific breakthrough	New technology	Spun off from a university with which it collaborates	R&D is the main activity of the firm
5	Science-based (Small science start-up)	1–10	Technological opportunity	New technology	Established collaboration with a new research organisation as part of the project	R&D is the main activity of the firm, which spun off from an R&D organisation
6	Science-based (Small manufacturing)	11–20	Market opportunity	New technology	Strong connection with one research organisation	R&D is the main activity of the firm and was important in developing the firm
7	Science-based (Medium manufacturing)	> 20	Technological opportunity	New technology	Several collaborations with research organisations	Internal R&D department and prior experience with R&D projects
8	Engineering-based (Medium engineering)	1–10	Market opportunity	New technology	Limited use of research organisations	Internal R&D department and prior experience with R&D projects
9	Engineering-based (Large process industry)	> 20	Market opportunity	Improved technology	Strong connection with one research organisation	Internal R&D department and long experience with R&D
10	Engineering-based (Large process industry)	> 20	Market opportunity	Improved technology	Strong connections with one research organisation and a university	Internal R&D team and long experience with R&D
11	Engineering-based (Large process industry)	11–20	Market opportunity	Improved technology	Several collaborations with (national and international) R&D organisations and universities	Internal R&D department and long experience with R&D
12	Network, several engineering-based firms (varying sizes)	11–20	Technological opportunity	Improved technology	Strong connection with an R&D organisation that played a central role in the project	Several smaller R&D projects have been conducted by the network partners

(*Continued*)

Table 1. (Continued).

Case	Type of firm (size* and industry)	Total budget (million NOK)**	Exploitation of technology (Autio, 1997)	Technology development (Autio, 1997)	R&D ties (Arrow, 1994; Asheim & Coenen, 2005)	R&D orientation (Autio, 1997)
13	Engineering-based (Medium engineering)	11–20	Technological opportunity	Improved technology	Spun off from an R&D organisation and has a strong relationship with a university	Internal R&D team and ongoing R&D
14	Engineering-based (Medium engineering)	1–10	Market opportunity	Improved technology	Collaboration with one main R&D organisation	Internal R&D team but low prior R&D experience
15	Engineering-based (Large process industry)	Not available	Market opportunity	Improved technology	Limited connections to R&D organisations	R&D team with internal and external members

*EU measures of firm size are used: large > 250 employees, medium < 250 employees, small < 50 employees, and micro < 10 employees.
**To preserve anonymity, we created a total budget range.

understanding of how the projects evolved and how additionalities were developed, our primary data consist of interviews with, on average, three key individuals from each case conducted five to 10 years after the firms received funding (2010–2011). We interviewed representatives from both firms and R&D organisations for each case (see Table 2), for a total of 40 individuals (32 face-to-face interviews and eight telephone interviews). We took a narrative approach to obtain an in-depth understanding of how the innovation projects unfolded in the cases (Polkinghorne, 1988), and the informants were asked to describe the process from inception to the present with minimal interruptions. We used an overall interview protocol with the objective of revealing the history of each project in chronological order, starting with the project background, planning, and execution and ending with the project results. To obtain additional information concerning the critical events and actors involved throughout the process, we asked follow-up questions, such as ‘Why did you do that’, ‘Who was involved’, ‘Did you consider alternative actions’, and ‘When did this happen?’ We used the narrative interviewing approach to obtain a better understanding of actual events and to prevent personal views and theoretical perspectives from influencing our data collection.

Our use of multiple informants and narrative interviewing in combination with historical documentation was crucial to reducing the problems of hindsight bias and memory decay. We took the aforementioned steps to improve the validity of retrospective reports and to ensure we obtained accurate data about the innovation projects and firm-level additionalities achieved over time (Miller et al., 1997). The interviews were mostly conducted with two researchers present and were audio-recorded and transcribed as part of the data-analysis process.

Table 2. Interviews and secondary data sources for each case.

Case project		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sum
Interviews	Firm project manager	x	x	x	x	x	x	x(p)	x	x	x	x	x	x	x	x(p)	15
	Firm researcher	x		x	x		x	x			x		x	xx		xxx(p)	12
	University project manager*						x	x			x	x		x	x	x(p)	7
	University researcher				x(p)			x		x	x(p)	x	x				6
Secondary data sources	Project description	x	x	x	x	x	x	x	na	x	x	x	x	x	x	x	14
	End report	x	x	x	x	x	x	x	na	x	x	x	x	x	x	x	14

(p) = phone interview, na = not available.
*University researcher with the role of manager of the university portion of the project.

Data analysis

Our abductive data-analysis process (Alvesson & Sköldberg, 2009) was highly iterative, including comparisons of the emerging findings and extant theory (Eisenhardt, 1989), and consisted of three main phases. First, we wrote a narrative case description of each case by triangulating the interviews and available documents. As a validity check, these case descriptions were approved by the respective project managers at the firms and discussed with contact persons at the BIP subsidy programme (Miller et al., 1997). Hence, we reconciled views from different sources, providing a thorough understanding of how the R&D projects unfolded over time. In this phase, we observed how the firms developed additionalities from the start of, during, and after the projects.

Second, we used qualitative analysis software (NVivo 12) to extend the theoretical framework of input, output, and behavioural additionalities. We systematically coded our empirical observations about the firm-level effects of conducting R&D projects both during and after the projects (Gioia et al., 2013; Miles et al., 2014). We identified similar codes of additionalities and clustered them in first-order categories before searching for linkages among the categories. This led to the development of sub-dimensions for input, output, and behavioural additionalities. We identified these sub-dimensions by iteratively juxtaposing our data with the existing literature on additionalities, which allowed us to confirm existing sub-dimensions (e.g., increased R&D activities) and develop new sub-dimensions (e.g., organisational goals) (Gioia et al., 2013).

Finally, during the coding process, we observed that the additionalities developed in the R&D projects differed depending on firm characteristics. Thus, we distinguished between the additionalities of science- and engineering-based firms (Autio, 1997; Chidamber et al., 1994) and developed a process model describing how these types of firms developed additionalities over time (Figure 1). To increase the rigour of the analytical generalisation of the empirical data, the iterative analyses were first independently conducted by two authors. The overall agreement was strong, and in the case of disagreement, the coding was discussed and modified until a common understanding was reached (Nag et al., 2007).

Findings

Our findings revealed patterns of how innovation projects supported by public R&D subsidies lead to the development of additionalities at the firm level. We find that different types of additionalities develop through a process in which different

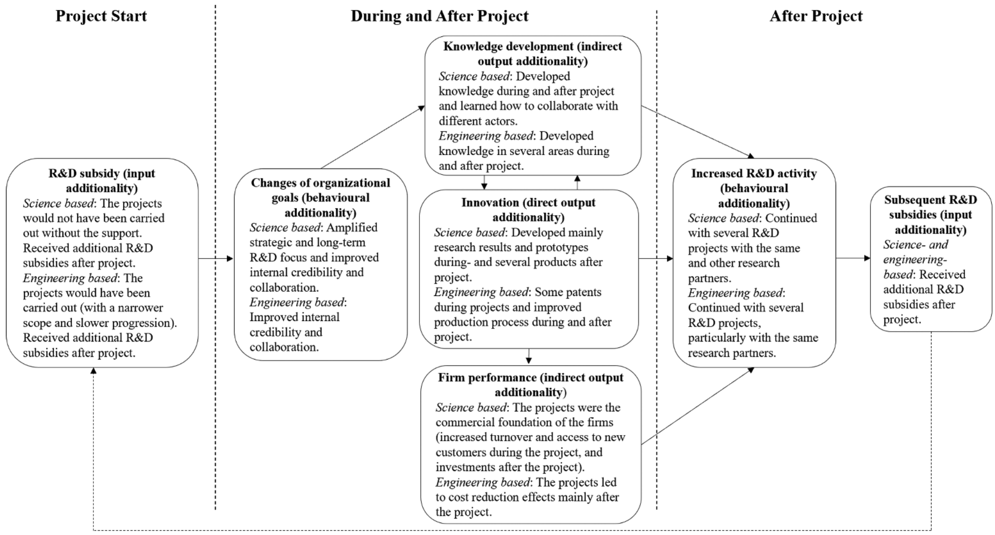

Figure 1. Process model on firm-level additionalities developed from subsidised R&D projects.

sub-dimensions of additionalities develop and interrelate from the start of, during, and after an R&D project. While the process of developing additionalities is similar for both science- and engineering-based firms, we find several key differences in how these two types of firms develop additionalities over time. Our findings are outlined in the process model in Figure 1 and presented in the following.

Project start

R&D subsidy (Input additionality)

As shown in our process model, all case firms described the public support they received as important for carrying out their projects but to different extents (see Table 3). The science-based firms (Firms 1–7) explained that the subsidised R&D projects were essential for developing their technologies: 'The support was essential for us [the firm], and we would not have carried out the project without it' (Firm 2). In contrast, all the engineering-based firms (Firms 8–15) explained that their projects would most likely have been carried out without the public support but with a narrower scope and slower progression: 'The projects would have been carried out [without the support] but not on the same scale or with the same university partners' (Firm 8).

During and after project

Based on the R&D subsidy at project start, our coding revealed that the science- and engineering-based firms developed *changes in organisational goals* (a sub-dimension of behavioural additionality) during the projects, which further developed into the indirect outputs of *knowledge development* and *firm performance* and the direct output of *innovation* during and after the projects (see Table 4).

Table 3. Additionalities for the science- and engineering-based firms at project start.

	Science-based firms (1–7)	Engineering-based firms (8–15)
The extent to which the project would have been carried out without public support (Clarysse et al., 2009) (input additionality)	**None of these projects would have been carried out without support**: *'The support was essential for the existence of the firm . . . and the support was important for us to work with several topics at the same time'* (Firm 1). *'We got access to the resources we needed to carry out the project'* (Firm 4).	**The projects would most likely have been carried out without public support but with a narrower scope and slower progression**: *'The project would probably have been much smaller [without the support] with fewer results. The financial support was vital internally for the firm to run this project'* (Firm 10). *'We would have continued with the same theme [without the support], but we would not have had the ability to invest the needed resources to reach the goals'* (Firm 15).

Changes in organisational goals (behavioural additionality)

Several of the science-based firms changed their behaviour as a result of their R&D projects by altering their organisational goals, which concern firms' desired outcomes and guide their actions (Kotlar et al., 2018). For the science-based firms, which worked with technologies at an earlier stage than the engineering-based firms, the R&D subsidies were related to a more apparent and clearer R&D focus. A member from a science-based firm explained that: 'The [support] forces us to define a goal . . .. Even though it is very easy to get distracted daily, we have had a goal. The goal has always been to launch a product that could be used' (Firm 1). By clarifying their organisational goals from the projects, these firms also garnered more credibility and engagement internally: 'I [the founder] worked as a consultant during the day with a couple of other employees and then worked with the [firm] group at night. We worked this way for three to four years' (Firm 2). Further, the changes in organisational goals from the project were manifested after the project end, as illustrated by a representative from a science-based firm: 'The project was at a micro scale, of which we were granted a patent. In the years that followed, we focused on industrialising our concept and ended up starting a firm to commercialise it' (Firm 3).

The R&D subsidies also led to changes in organisational goals related to internal credibility and collaboration, particularly during but also after the project for the engineering-based firms:

> The R&D subsidy was substantial as we could say we got support from the Research Council, and then, we got acceptance internally [in the firm] . . .. [The support] triggered both who we were involved with [internally and externally] and the size of the contribution in the project. (Firm 9)

In a similar vein, an individual from Firm 11 noted, 'The [support] was important for anchoring the project internally in the company . . . and the [support] enabled us to connect our technology engineers in other firm areas'.

Hence, we observed that changes in organisational goals guided the actions of the engineering-based firms in terms of improved internal credibility and collaboration. A member from an engineering-based firm explained the challenges the firm faced in plant operations before the R&D project: 'We did not have full control over all of the processes in the factory . . . and there were many different attempts to solve the problem;

Table 4. Additionalities developed during and after the projects for the science- and engineering-based firm.

		Organisational goals (behavioural)	Knowledge development (Hsu et al., 2009) (indirect output)	Innovation (Clarysse et al., 2009) (direct output)	Firm performance (Ciabuschi et al., 2020; Georghiou, 2002) (indirect output)
Science-based firms (1–7)	During project	**Changes in organisational goals that amplified the firms' strategic and long-term R&D orientation and improved the firms' internal credibility and collaboration**: *'The support had a stabilising effect during the actual project period; it was easier to maintain the level of R&D ambition and to avoid a situation in which people were prioritised for other tasks'* (Firm 7).	**Developed knowledge in several areas and learned how to collaborate with different actors**: *'Knowledge is our most important output, and it has many dimensions: increased networking, accumulated knowledge over time, and knowledge that in turn can generate new ideas'* (Firm 7). *'We got in good contact with [the supplier], which we enjoy the fruits of in other contexts, as well. We learned how they could contribute to our work'* (Firm 5).	**Developed mainly research results and prototypes**: *'Even though it was a user-driven project, it was basic research. The technology we developed can be used for very many purposes'* (Firm 2).	**The projects were the commercial foundation for the firms, contributing to increased turnover and access to new customers**: *'Had it not been for the Research Council, the company simply would not have existed'* (Firm 1). *'The [project] led us to get [a large customer]. We also got some funds from [another firm] . . .. We got a lot of attention from actors in the environment, so that generated some income, too'* (Firm 2).
	After project	**The changes were manifested after the project**: *'In our application to the research council, we wrote that the goal in this project was to develop a market-ready product. But, in retrospect, the project can be considered a pre-study. It was the first milestone to realise our goal of commercialisation'* (Firm 4)	**Further knowledge development**: *'The competence from the projects has been vital. It is the reason why we were able to become a partner in EU projects and to work together with [larger international firms] in new R&D projects'* (Firm 2).	**Developed several products and spin-off products**: *'Because of this [the project and its results], we later came up with a larger project over three years to try to get products out to the market'* (Firm 4).	**Further growth and investments from different sources for several firms**: *'Today, we sell for 6–700 million NOK based on the project'* (Firm 1). *'I was invited to [meet with] a group of [international] investors that would like to invest and take this further'* (Firm 2).

(*Continued*)

Table 4. (Continued).

		Organisational goals (behavioural)	Knowledge development (Hsu et al., 2009) (indirect output)	Innovation (Clarysse et al., 2009) (direct output)	Firm performance (Ciabuschi et al., 2020; Georghiou, 2002) (indirect output)
Engineering-based firms (8–15)	During project	**Changes in organisational goals that improved the firms' internal credibility and collaboration**: *'The project led to closer collaboration between [Departments X and Y]'* (Firm 11). *'We had three factories as a pilot. They helped to develop all these [tools]. There was close collaboration . . .. Especially, [Plant X] was active and tried out the tools we developed and considered their value. They used [tools] regularly every day'* (Firm 9).	**Developed knowledge in several areas**: *'We've got a more knowledgeable staff. Through customer dialogue [during the project], we have acquired insights and knowledge, and we have developed new products'* (Firm 8). *'The [project] contributed to a huge competence-building effect, but we always try to link this effect to concrete technical challenges, where one can demonstrate that it gives results in practice'* (Firm 9).	**Improved production process and some patents**: *'During this project, a new concept was developed that more than halved the costs [of the process improvement]'* (Firm 9).	
	After project	**The changes were manifested after the project**: *'These enabling technologies have matured over time, and were introduced in the marked quite recently* [seven years after project end] *. . . But there is still some work that needs to be done to realise the opportunities that were developed in the project . . . We are now working with the next* [product] *generation'* (Firm 13). *'The project developed a consciousness of the importance of R&D. We have invested a lot after the project ended, the understanding and the necessity of these investment was developed in this project'* (Firm 14).	**Further knowledge development**: *'The [project] also contributed to knowledge development in the company that has originated new projects and requests from customers about other deliveries'* (Firm 8). *'The project is therefore a [knowledge] foundation in further development of improving the [production process]'* (Firm 9).	**Further development of production processes**: *'Because of the project, the concept has been further developed and the costs have been further reduced significantly as the [production process] was improved'* (Firm 9).	**The projects led to growth and cost reductions**: *'The sales figures that can be directly related to this project are estimated to be somewhere between 2 and 3 billion [NOK]'* (Firm 8) *'The savings for [the firm] can be estimated at millions per year, of which this project has been very important to achieve these savings'* (Firm 9).

there were up to 10 different attempts at the same time' (Firm 15). The subsidised R&D project was essential in solving these challenges through better internal credibility and collaboration between different departments: 'We were able to solve some of the challenges in the factories through good relations between technology and operations; we worked closely together for two years' (Firm 15). These changes were also manifested after project end, as a member from an engineering-based firm stated: 'The [result of the project] have been further developed over the years, but the core, the idea, was developed in this project' (Firm 14). A member from another engineering-based firm added: 'Several ideas that were worked on [in the project] have become building blocks for new solutions' (Firm 13).

Knowledge development (Indirect output additionality)

Based on changes in organisational goals, the science- and engineering-based firms developed an extensive amount of knowledge from conducting the R&D projects. For both types of firms, the knowledge developed during the projects served as a basis for further developing their core competences after the projects ended, as explained by a representative from Firm 7: 'The principles that we learned in this project can benefit us even more in the future. The [knowledge] has functioned as a platform for what we have done and a little more'. Representatives from the engineering-based firms described the knowledge they realised through their projects in a similar way: 'This expertise has been of great value and has become one of the two processes where [the firm] has heavy professional environments today' (Firm 15). A member of another engineering-based firm also highlighted increased competences among employees involved in the firm's project: 'The project had 20 to 30 core people [involved] who have become better at technical and commercial aspects' (Firm 12).

We also observed that some of the firms in both groups failed in parts of their innovation projects. However, these firms learned from their failures, which they benefitted from after the projects ended. One example is the engineering-based Firm 11, where one out of three sub-projects failed: 'The product proved not to be competitive on price, but it [the product] has given us expertise ... that has been used in other areas, which shows that we succeeded gradually by using that knowledge'. A representative from a science-based firm that failed to develop its main product in its project expressed the following:

> Seen in retrospect, I have learned so many things that we should have done differently [in the project period and later]. We have learned the hard way. However, the results [from the project] have also been central to [the firm] in the development of other products. (Firm 2)

Some of the science-based firms also reported knowledge development associated with how the firms were learning to collaborate with different partners. The subsidised R&D projects were an important arena for collaborating with different types of R&D partners (both national and international), as explained by a representative from Firm 4: 'We learned a lot about how it is to work with other academic institutions that are not in Norway'.

Innovation (Direct output additionality)

Our process model further shows an interrelationship between knowledge development and innovation, illustrated by the arrows in Figure 1. Based on the knowledge development from the projects, the science-based firms mainly developed research results and prototypes during their projects, which were further developed into products and related spin-off products after the projects ended: 'We needed to produce results, and we got it. On top of that, we even made one more product' (Firm 2). Consequently, the project outcomes leveraged further knowledge development after project end, as explained by a representative in Firm 3: 'After the project, we have also realised that the method can be used for other elements. We have expanded our knowledge horizon in terms of [a particular area] . . . and that can be useful in the future'.

The engineering-based firms developed specific innovation outputs both during and after their R&D projects. These firms already had existing technologies that they then improved through applied research within a shorter time horizon, as explained by a representative from Firm 15: 'The project contributed significantly in understanding and solving the [problems] in the production process . . .. But this is a theme that we still work on. You never reach the target; you can always improve [the production process]'. A representative from Firm 13 noted something similar: 'A lot of the things that were done [in the project] have continued and matured over time'.

Firm performance (Indirect output additionality)

Based on the innovation outputs developed during the projects, both the science- and engineering-based firms developed output additionality related to firm performance. Here, the science-based firms developed their firm performance related to core technology development, growth rate, and investments both during and after their projects, whereas the engineering-based firms mainly experienced cost-reductions after their projects.

For several of the science-based firms, the subsidised R&D projects were of key importance for firm performance: 'The [product] was the first thing we did in [the firm]. So, if we hadn't got [the project], we would have been shut down' (Firm 2). For these micro- to medium-sized firms, the projects were their main activities and crucial for developing their core technologies, as explained by a member of Firm 1: 'The [project] is really the whole foundation for the creation of [the firm]'.

Furthermore, the projects contributed to the science-based firms' growth during and after the projects: 'We have sold [a large number of products] in total, and our sales are growing' (Firm 1). Another science-based firm linked its high growth rate to its project: 'For [the firm], this project was the start of a very positive development where the sales increased from 4 million [NOK] in 1996 to 65 million [NOK] in 2001. This increase can mainly be attributed to [the technology from this project]' (Firm 6).

We also observed that many of the science-based firms received funding from several other sources, such as private investors (national and international), venture funds, seed funds, and the Norwegian Government's agency for innovation (Innovation Norway). This funding was often linked to the subsidised R&D projects, as explained by a representative from Firm 1: 'Relatively shortly after we had started, we got a committed long-term investor who was willing to spend money on us. This was before we had made any products, and we were still at the idea stage'. Indeed, the initial public support for these projects often served as a catalyst for additional grants and funding from other sources:

> We found a [international] company that has specialised knowledge of [the process] . . . and they came to Norway to run experiments and further development. We got funding from both [international] and Norwegian foundations and from the Research Council of Norway, which also was a good basis for talking to investors . . . and then we opened for other investors, seed funds, and venture funds. (Firm 3)

Output additionality related to firm performance was less apparent for the engineering-based firms that experienced cost reductions from their improved production processes as outputs after their projects: 'The savings for [the firm] can be estimated at tens of millions a year, of which this project has been very central in achieving' (Firm 9), and 'The improvements made during the project period have a value of over 100 million NOK annually, and the other facilities would not have been built [without the project]' (Firm 15).

After project

Based on changes in organisational goals, knowledge development, innovation, and firm performance during and after the projects, both the science- and engineering-based firms increased their R&D activity (behavioural additionality). This could be seen as an input additionality, where the firms received subsequent R&D subsidies after the projects ended (see Table 5).

Increased R&D activity (Behavioural additionality)

We found that both the science- and engineering-based firms increased their R&D activities. The science-based firms continued to collaborate with several research partners, such as national and international universities and R&D institutes, including both familiar and unfamiliar partners: 'We are still collaborating with [the same university partner], and we have new R&D projects with [European research institutes] and some EU projects' (Firm 6).

The engineering-based firms also continued with several R&D projects after the subsidised projects were completed but mostly in collaboration with known research partners: 'A key person at [the R&D institute] has followed us for 20 years. He is still there and is often used in new projects' (Firm 10). Compared to the science-based firms, the engineering-based firms were more intentional in building relationships with and ensuring the competence of researchers they could work with over the long run: 'It is a strategic choice regarding which research institutes you want to pursue and develop over time; these are the ones you choose' (Firm 12). This might explain why some researchers from the R&D organisations were employed by the firms after the projects ended: 'I started working [in the firm] to continue developing this process further' (Firm 9).

Subsequent R&D subsidies (Input additionality)

All firms, except for two engineering-based firms (12 and 15), received further R&D subsidies within five to 10 years after their projects ended (see Table 3): 'After [the current project], we received grants through two [R&D projects] that aimed to develop

Table 5. Additionalities developed after the projects for the science- and engineering-based firms.

	Increased R&D activities (Hsu et al., 2009) (behavioural additionality)	The extent of R&D subsidies received after the project ended (Falk, 2007) (input additionality)
Science-based firms (1–7)	**Continued with several R&D projects with the same and other research partners**: *'We have collaborated with national and international universities'* (Firm 4). *'We found a firm in [a European country] that is specialised in [analysis]. They work in [another industry than Firm 3], so it was hard to get them onboard at first, but luckily, they got fired up about the idea and came to Norway to run experiments with us'* (Firm 3).	**All firms received R&D subsidies after their subsidised projects mainly from similar R&D programmes but also from larger programmes**: *'We have received EU funds after [the subsidised R&D project]'* (Firm 1). *'We were granted with support [from the same R&D programme] to continue developing the technology [from the subsidised R&D project'* (Firm 3).
Engineering-based firms (8–15)	**Continued with several R&D projects, particularly with the same research partners**: *'[The project] built a lot of expertise also for the external contributors, especially in regard to [one of the university partners], that they have used in other projects afterward'* (Firm 11). *'After the project ended, we recruited one of the PhD candidates [from the university partner] who worked on the project'* (Firm 11).	**All firms (except Firms 12 and 15) received R&D subsidies after their subsidised projects mainly from similar R&D programmes but also from larger programmes**: *'We received grants for two [R&D projects] from the Research Council of Norway'* (Firm 9). *'From the [subsidised R&D project], we applied for two new projects funded by the Research Council of Norway, which contributed to interesting projects after this [the subsidised] project … and we now participate in a [research centre]'* (Firm 14).

the product further, with a total budget of 55 million NOK … ' (Firm 4). These R&D subsidies were mainly granted by similar R&D programmes, but several of the firms received subsidies from larger and more long-term R&D programmes, such as from research centres and EU funds.

Discussion

This study provides detailed processual evidence of how different firm-level additionalities from publicly subsidised R&D projects develop and interrelate over time (Clarysse et al., 2009; Dimos & Pugh, 2016; Falk, 2007).

First, our process model (Figure 1) shows that for the science-based firms, the public support was essential for carrying out the R&D projects as they were developing the core technologies of their businesses and had a strong need for external resources (Peng & Liu, 2018). The engineering-based firms were typically more established firms that needed to constantly strengthen their competitive advantage through technology improvements. These firms would most likely have carried out parts of the projects without the support (Clarysse et al., 2009) but with a narrower scope and slower progression.

Then, our process model illustrates how input additionality interrelates with behavioural additionality (Clarysse et al., 2009). This interrelationship is mainly related to how input additionalities were changing firms' goals through their research activities. As such, the increased R&D activities in the subsidised R&D projects (input additionality) seem to have an influence on the firms' organisational goals (sub-dimension of behavioural additionality). Both the science- and engineering-based firms formalised more ambitious goals for their R&D projects, which also guided their actions (Kotlar et al., 2018). For the science-based firms, the R&D subsidies created a more apparent and clearer R&D focus, which pushed these firms to achieve their overarching goals related to building their market positions both during and after the projects. For the engineering-based firms, which were larger and operated in more mature markets, the public support was particularly important for coordinating different sections and employees within the firms and for enhancing internal credibility and collaboration to reach these firms' common organisational goals (Davenport et al., 1998), especially during the projects. We show that firms provide additional resources to publicly funded R&D projects (Falk, 2007) by channelling internal resources (employees) into the projects. Hence, the projects are used to coordinate the firms' innovation activities, particularly for larger engineering-based firms.

Next, our process model shows how clarifying the firms' organisational goals can facilitate stronger knowledge development based on R&D. The science-based firms aimed to exploit scientific breakthroughs, which required specialised knowledge (Laursen & Salter, 2006) from different partners (Kobarg et al., 2019). In contrast, the engineering-based firms mostly developed incremental innovations that required more similar knowledge bases (Tsai, 2001), which they typically gained from partners they were already familiar with. Although the firms focused only on the successful results from the projects when reporting to governmental officials, some of the firms also failed in parts of the projects. However, these failures were described by the firms as learning opportunities that contributed with knowledge to the firms' innovation processes and subsequent R&D projects. Hence, we confirm that knowledge gained from failures enables subsequent firm success (Maidique & Zirger, 1985) and that failures associated with R&D projects can be considered as valuable to the firms' overall innovation processes. Hence, we assert that behavioural additionalities can strengthen output additionalities (Davenport et al., 1999), indicating an interrelationship between changes in organisational goals and knowledge development.

Our process model further identifies an interrelationship between the two sub-dimensions of output additionality – knowledge development and innovation (Frenz & Ietto-Gillies, 2009) – indicating a reinforced and ongoing interrelationship between these two dimensions (illustrated by the arrows in Figure 1). The type of R&D conducted in the projects influenced the timing of the innovation outputs. The science-based firms mainly conducted long-term basic research that resulted in innovations several years after the projects ended, which illustrates why subsidies typically have long-term impacts (Bernini et al., 2017). In contrast, the engineering-based firms developed more incremental innovation outputs during and after the projects because their motivation was to do more short-term and applied research that could provide a competitive edge related to their existing products and processes.

Moreover, our process model highlights an interrelationship between the output additionality sub-dimensions of innovation and firm performance. For the science-based firms, the innovation outputs from the R&D projects served as these firms' commercial foundation, contributing to increased employee recruitment and access to customers (Georghiou, 2007). Some of these firms also received external investments, showing that public subsidies of innovation projects might provide a quality signal (Georghiou, 2007) that reduces risk and makes it more attractive for others to invest in new technology-based firms in the early stages of their development (Meuleman & De Maeseneire, 2012; Söderblom et al., 2015). The engineering-based firms were more concerned with sustaining their market positions through incremental process innovations, which frequently contributed to cost efficiency (Hervas-Oliver et al., 2014; Menguc et al., 2014), rather than the high growth rates associated with breakthrough product innovations in the long run (Hervas-Oliver et al., 2014; McDermott & O'Connor, 2002). These findings add nuance to recent studies showing how additionalities in terms of increased turnover are higher for smaller and less-developed firms (Vanino et al., 2019). Our study shows that compared to science-based firms, larger engineering-based firms are more likely to increase their financial revenues based on more incremental innovations, which contribute to securing their competitive positions.

Furthermore, increased firm performance provides firms with the resources and competences needed to expand their R&D activities after a project ends. Hence, the output additionality sub-dimension of firm performance can strengthen the behavioural additionality sub-dimension of increased R&D activities over time. However, we observed differences between the science- and engineering-based firms regarding the type of R&D projects they conducted and with whom they collaborated after their projects were completed. The science-based firms continued with several R&D projects with the same and other research partners, whereas the engineering-based firms continued with several R&D projects with the same research partners. This may be related to the firms' stage of development and the maturity of their technologies and processes. The science-based firms mainly developed science-based technologies that required world-leading research and thus diverse partnerships, whereas the engineering-based firms depended more on specific research partners with in-depth knowledge of the firms' processes (Katila & Ahuja, 2002).

Finally, our process model illustrates how increased R&D activities can reinforce the firm's R&D activity after a project ends. Almost all our case firms received subsequent R&D subsidies after the projects examined in this study (Ciabuschi et al., 2020; Falk, 2007; Wanzenböck et al., 2013). Hence, the behavioural additionalities resulting from the first project were important for getting new subsidies, and the learning achieved in one project was integrated into the next (Georghiou, 2002).

Conclusions and implications

By examining 15 innovation projects longitudinally, we increase the knowledge on how different firm-level additionalities from publicly subsidised R&D projects are achieved and how they interrelate over time. The findings provide three main contributions.

First, a key contribution is linked to how different additionalities from subsidised R&D projects develop and interrelate over time (Clarysse et al., 2009; Dimos & Pugh, 2016; Falk, 2007; Kochenkova et al., 2016). We found that additionalities develop through a process in which sub-dimensions of additionalities develop and interrelate at different stages of an R&D project (i.e., at the start of, during, and after the project). Input, behavioural, and output additionalities can reinforce each other during and after a project, which illustrates why R&D subsidies typically have long-term impacts (Bernini et al., 2017) and are enhanced by collaboration (Chapman et al., 2018). As such, we add to the discussion on the innovation policy mix (Dumont, 2017; Radicic & Pugh, 2017) by emphasising how R&D subsidies can influence firms' use of policy instruments at later points in time.

Second, in line with previous research highlighting the need to distinguish between different types of firms (Aerts & Schmidt, 2008; Dimos & Pugh, 2016) to explain the mixed results of additionalities (Cerulli et al., 2016; Dimos & Pugh, 2016; Zúñiga-Vicente et al., 2014), we show how science- and engineering-based firms rely on and use R&D subsidies in different ways. For *science-based firms*, subsidies appear to mainly increase innovation and knowledge development and enhance firms' strategic and long-term R&D orientation. For *engineering-based firms*, subsidies mainly leverage internal credibility and collaboration within these firms, which leads to more R&D activities. Hence, additionalities are not uniform across different types of firms, thus illustrating why evaluating public R&D subsidies in heterogeneous samples has proven to be challenging (Dimos & Pugh, 2016).

Third, by operationalising sub-dimensions of output and behavioural additionalities, we contribute more in-depth insights into the content of additionalities (Clarysse et al., 2009; Kochenkova et al., 2016), which have been critiqued for being challenging to operationalise and measure and fraught with timing issues (Clarysse et al., 2009). We confirm three sub-dimensions of output additionalities from the existing research – innovation (Clarysse et al., 2009), knowledge development (Hsu et al., 2009), and firm performance (Ciabuschi et al., 2020; Georghiou, 2002). Both groups of firms developed innovation and knowledge during and after their projects, whereas firm performance manifested in different ways. The subsidised projects were the commercial foundation for the science-based firms, contributing to increased turnover and access to new customers and investors during and after the projects, whereas the engineering-based firms experienced increased growth and cost reductions after their projects.

Moreover, we extend the behavioural additionality concept, which is not well understood (Gök & Edler, 2012), by suggesting the new sub-dimension of changes in organisational goals. We found that the science-based firms changed their organisational goals mainly by giving their publicly funded R&D activities higher priority, while the engineering-based firms mainly developed internal credibility and collaboration because of the projects. We further confirm and extend the sub-dimension of increased R&D activities from prior research (Hsu et al., 2009) and show how it develops. The science-based firms continued to collaborate with several research partners after the subsidised project, such as national and international universities and R&D institutes, including both familiar and unfamiliar partners. The engineering-based firms also continued with several R&D projects after the projects were completed but mostly in collaboration with known research partners (Steinmo & Rasmussen, 2016).

Implications for practice

Our study shows how additionalities of public R&D subsidies are developed and can emerge over long time periods. This knowledge provides important implications for how policymakers can design R&D support schemes depending on the goals to be achieved.

Subsidies with long-term goals will probably have a stronger effect if they trigger behavioural additionality, which induces higher R&D investments by firms over time. Thus, our study illustrates how a specific policy instrument can spur behavioural additionality, which leads firms to use other policy instruments in the future, as illustrated by our process model in Figure 1. Indeed, most firms in our study received subsequent public support to continue their innovation projects. Hence, firms with lower levels of R&D experience may need to pursue smaller projects with higher levels of support to learn, develop outputs, and change their behaviour to make more investments in R&D. An effective approach is probably a policy mix that provides funding for firms to gradually develop their R&D expertise through behavioural additionality as well as grants to support larger projects over time. Moreover, our findings show how knowledge can be developed from failures in parts of the projects. Hence, learning from failures should be considered as an outcome from subsidised R&D projects.

Moreover, we show how the development of additionalities may differ depending on firm characteristics. While the engineering-based firms in our study showed strong direct innovation outputs related to their subsidies, the science-based firms seemed to create stronger long-term additionalities. Thus, policy initiatives should consider using different evaluation criteria for support given to these types of firms.

Limitations and implications for further research

Using a qualitative, longitudinal, and theory-building approach (Dimos & Pugh, 2016; Falk, 2007; Kochenkova et al., 2016), we mapped a process that has been scarcely investigated in the literature. Our context and sample, which include only successful projects, are suitable for revealing how the variety of additionalities interrelate, but the overall additionalities cannot be directly generalised to the full population of projects or other contexts. Indeed, public R&D subsidies seem to have higher additionalities for high-quality projects (Hünermund & Czarnitzki, 2019; Marino et al., 2016). Hence, the additionalities reported in our cases are probably much stronger than average, and further research is needed to examine these additionalities in more representative samples.

All cases are from a single country and a specific subsidy programme. Norway is a small and relatively wealthy country with an R&D intensity close to the OECD average. Due to the small domestic market, all the firms in our sample are more or less export oriented, and some can be considered multinationals or born globals. The type of R&D subsidy scheme investigated here is common in many countries and still persists as a large scheme in Norway. Hence, the findings from this study are probably relevant in the context of science- and engineering-based firms in other developed countries.

Another limitation is related to the endogeneity of the support (Szczygielski et al., 2017). The firms were selected because they reported high value added from their subsidies, which raises the question as to whether these firms would have still performed well without the public support. Because the purpose of this study was to identify the development of additionalities and their interrelationships rather than the size of these effects, the main findings are not likely to be invalidated by such endogeneity problems. However, studies seeking to evaluate the absolute or relative causal effects of R&D subsidies on the different additionality dimensions need to apply research designs or methods that deal with endogeneity issues (e.g., omitted variables or selection biases) that could potentially overestimate the effects (Dimos & Pugh, 2016). Our process model shows the importance of accounting for firm characteristics when studying the additionalities of R&D subsidies to reduce the effects of unobserved firm heterogeneity (Aerts & Schmidt, 2008; Dimos & Pugh, 2016).

Finally, this study was limited to firm-level additionalities for the lead firms of the subsidised projects, but the benefits from the projects likely had a much broader reach with benefits for collaborating firms, academic partners, and society at large (Fini et al., 2018). The variety of additionalities from public R&D subsidies makes it difficult to quantitatively assess the additionalities of subsidies. Ideally, evaluations of public subsidies should include a variety of measures related to input, behavioural, and output additionalities and should map over longer time periods and for different stakeholders.

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References

Aerts, K., & Schmidt, T. (2008). Two for the price of one?: Additionality effects of R&D subsidies: A comparison between Flanders and Germany. *Research Policy*, *37*(5), 806–822. https://doi.org/10.1016/j.respol.2008.01.011

Aguiar, L., & Gagnepain, P. (2017). European cooperative R&D and firm performance: Evidence based on funding differences in key actions. *International Journal of Industrial Organization*, *53*, 1–31. https://doi.org/10.1016/j.ijindorg.2016.12.007

Alvesson, M., & Sköldberg, K. (2009). *Reflexive methodology: New vistas for qualitative research*. Sage.

Arrow, K. (1994). *The production ans distribution of knowledge. The economics of growth and technical change: Technologies, nations, agents*. (G. Silverberg & L. Soete, Eds.). (pp. 9–19). Aldershot: Edgard Elgar.

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In R. Nelson (Ed.), *The rate and direction of inventive activity* (pp. 609–625). Princeton University Press.
Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, *34*(8), 1173–1190. https://doi.org/10.1016/j.respol.2005.03.013
Autio, E., Kanninen, S., & Gustafsson, R. (2008). First-and second-order additionality and learning outcomes in collaborative R&D programs. *Research Policy*, *37*(1), 59–76. https://doi.org/10.1016/j.respol.2007.07.012
Autio, E. (1997). New, technology-based firms in innovation networks symplectic and generative impacts. *Research Policy*, *26*(3), 263–281. https://doi.org/10.1016/S0048-7333(96)00906-7
Bernini, C., Cerqua, A., & Pellegrini, G. (2017). Public subsidies, TFP and efficiency: A tale of complex relationships. *Research Policy*, *46*(4), 751–767. https://doi.org/10.1016/j.respol.2017.02.001
Bianchi, M., Murtinu, S., & Scalera, V. G. (2019). R&D subsidies as dual signals in technological collaborations. *Research Policy*, *48*(9), 103821. https://doi.org/10.1016/j.respol.2019.103821
Bodas Freitas, I., Castellacci, F., Fontana, R., Malerba, F., & Vezzulli, A. (2017). Sectors and the additionality effects of R&D tax credits: A cross-country microeconometric analysis. *Research Policy*, *46*(1), 57–72. https://doi.org/10.1016/j.respol.2016.10.002
Bræin, L., Hervik, A., Bremnes, H., & Bergem, B. G. (2009). *Resultatmåling av brukerstyrt forskning 2007*. Møreforsking.
Bronzini, R., & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. *Research Policy*, *45*(2), 442–457. https://doi.org/10.1016/j.respol.2015.10.008
Buisseret, T. J., Cameron, H. M., & Georghiou, L. (1995). What difference does it make? Additionality in the public support of R&D in large firms. *International Journal of Technology Management*, *10*(4–6), 587–600. https://doi.org/10.1504/IJTM.1995.025644
Cerulli, G., Gabriele, R., & Potì, B. (2016). The role of firm R&D effort and collaboration as mediating drivers of innovation policy effectiveness. *Industry and Innovation*, *23*(5), 426–447. https://doi.org/10.1080/13662716.2016.1169159
Chapman, G., & Hewitt-Dundas, N. (2018). The effect of public support on senior manager attitudes to innovation. *Technovation*, *69*, 28–39. https://doi.org/10.1016/j.technovation.2017.10.004
Chapman, G., Lucena, A., & Afcha, S. (2018). R&D subsidies & external collaborative breadth: Differential gains and the role of collaboration experience. *Research Policy*, *47*(3), 623–636. https://doi.org/10.1016/j.respol.2018.01.009
Chidamber, A., Shyam, R., & Henry, B. (1994). Research retrospective of innovation inception and success: The technology-push, demand-pull question. *International Journal of Technology Management*, *9*(1), 94–112. https://doi.org/10.1504/IJTM.1994.025565
Ciabuschi, F., Baraldi, E., Lindahl, O., & Callegari, S. (2020). Supporting innovation against the threat of antibiotic resistance: Exploring the impact of public incentives on firm performance and entrepreneurial orientation. *Journal of Business Research*, *112*, 271–280. https://doi.org/10.1016/j.jbusres.2019.12.021
Clarysse, B., Wright, M., & Mustar, P. (2009). Behavioural additionality of R&D subsidies: A learning perspective. *Research Policy*, *38*(10), 1517–1533. https://doi.org/10.1016/j.respol.2009.09.003
Czarnitzki, D., & Hussinger, K. (2018). Input and output additionality of R&D subsidies. *Applied Economics*, *50*(12), 1324–1341. https://doi.org/10.1080/00036846.2017.1361010
Davenport, S., Davies, J., & Grimes, C. (1999). Collaborative research programmes: Building trust from difference. *Technovation*, *19*(1), 31–40. <go to isi>://WOS:000078110800002. https://doi.org/10.1016/S0166-4972(98)00083-2
Davenport, S., Grimes, C., & Davies, J. (1998). Research collaboration and behavioural additionality: A New Zealand case study. *Technology Analysis & Strategic Management*, *10*(1), 55–68. https://doi.org/10.1080/09537329808524304
Dimos, C., & Pugh, G. (2016). The effectiveness of R&D subsidies: A meta-regression analysis of the evaluation literature. *Research Policy*, *45*(4), 797–815. https://doi.org/10.1016/j.respol.2016.01.002

Dumont, M. (2017). Assessing the policy mix of public support to business R&D. *Research Policy*, *46*(10), 1851–1862. https://doi.org/10.1016/j.respol.2017.09.001
Eisenhardt, K. M. (1989). Building theories from case study research. *The Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.2307/258557
Falk, R. (2007). Measuring the effects of public support schemes on firms' innovation activities: Survey evidence from Austria. *Research Policy*, *36*(5), 665–679. https://doi.org/10.1016/j.respol.2007.01.005
Fini, R., Rasmussen, E., Siegel, D., & Wiklund, J. (2018). Rethinking the commercialization of public science: From entrepreneurial outcomes to societal impacts. *Academy of Management Perspectives*, *32*(1), 4–20. https://doi.org/10.5465/amp.2017.0206
Frenz, M., & Ietto-Gillies, G. (2009). The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey. *Research Policy*, *38*(7), 1125–1135. https://doi.org/10.1016/j.respol.2009.05.002
George, G., Zahra, S. A., & Wood, D. R. (2002). The effects of business–university alliances on innovative output and financial performance: A study of publicly traded biotechnology companies. *Journal of Business Venturing*, *17*(6), 577–609. https://doi.org/10.1016/S0883-9026(01)00069-6
Georghiou, L., Clarysse, B., & Steurs, G. (2004). *'Making the difference': The evaluation of'behavioural additionality'of R & D subsidies*. IWT.
Georghiou, L., & Clarysse, B. (2006). Introduction and synthesis, in government R&D funding and company behaviour. In *Measuring behavioural additionality* (pp. 9–38). OECD.
Georghiou, L. (2002). Additionality and impact of R&D subsidies. *IWT Studies*, *40*, 57–64.
Georghiou, L. (2007). What lies beneath: Avoiding the risk of under-evaluation. *Science and Public Policy*, *34*(10), 743–752. https://doi.org/10.3152/030234207X259003
Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151
Gök, A., & Edler, J. (2012). The use of behavioural additionality evaluation in innovation policy making. *Research Evaluation*, *21*(4), 306–318. https://doi.org/10.1093/reseval/rvs015
Herrera, L., & Sánchez-González, G. (2013). Firm size and innovation policy. *International Small Business Journal: Researching Entrepreneurship*, *31*(2), 137–155. https://doi.org/10.1177/0266242611405553
Hervas-Oliver, J.-L., Sempere-Ripoll, F., & Boronat-Moll, C. (2014). Process innovation strategy in SMEs, organizational innovation and performance: A misleading debate? *Small Business Economics*, *43*(4), 873–886. https://doi.org/10.1007/s11187-014-9567-3
Howell, S. T. (2017). Financing innovation: Evidence from R&D grants. *American Economic Review*, *107*(4), 1136–1164. https://doi.org/10.1257/aer.20150808
Hsu, F.-M., Horng, D.-J., & Hsueh, -C.-C. (2009). The effect of government-sponsored R&D programmes on additionality in recipient firms in Taiwan. *Technovation*, *29*(3), 204–217. https://doi.org/10.1016/j.technovation.2008.05.001
Hud, M., & Hussinger, K. J. R. (2015). The impact of R&D subsidies during the crisis. *Research Policy*, *44*(10), 1844–1855.
Hünermund, P., & Czarnitzki, D. (2019). Estimating the causal effect of R&D subsidies in a pan-European program. *Research Policy*, *48*(1), 115–124. https://doi.org/10.1016/j.respol.2018.08.001
Katila, R., & Ahuja, G. (2002). Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal*, *45*(6), 1183–1194. https://doi.org/10.5465/3069433
Knockaert, M., Spithoven, A., & Clarysse, B. (2014). The impact of technology intermediaries on firm cognitive capacity additionality. *Technological Forecasting and Social Change*, *81*, 376–387. https://doi.org/10.1016/j.techfore.2013.05.007
Kobarg, S., Stumpf-Wollersheim, J., & Welpe, I. M. (2019). More is not always better: Effects of collaboration breadth and depth on radical and incremental innovation performance at the project level. *Research Policy*, *48*(1), 1–10. https://doi.org/10.1016/j.respol.2018.07.014

Kochenkova, A., Grimaldi, R., & Munari, F. (2016). Public policy measures in support of knowledge transfer activities: A review of academic literature [journal article]. *The Journal of Technology Transfer*, *41*(3), 407–429. https://doi.org/10.1007/s10961-015-9416-9

Kotlar, J., De Massis, A., Wright, M., & Frattini, F. (2018). Organizational goals: Antecedents, formation processes and implications for firm behavior and performance. *International Journal of Management Reviews*, *20*(S1), S3–S18. https://doi.org/10.1111/ijmr.12170

Lanahan, L., & Feldman, M. P. (2015). Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program. *Research Policy*, *44*(7), 1387–1402. https://doi.org/10.1016/j.respol.2015.04.002

Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, *27*(2), 131–150. https://doi.org/10.1002/smj.507

Maidique, M. A., & Zirger, B. J. (1985). The new product learning cycle. *Research Policy*, *14*(6), 299–313. https://doi.org/10.1016/0048-7333(85)90001-0

Marino, M., Lhuillery, S., Parrotta, P., & Sala, D. (2016). Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. *Research Policy*, *45*(9), 1715–1730. https://doi.org/10.1016/j.respol.2016.04.009

McDermott, C. M., & O'Connor, G. C. (2002). Managing radical innovation: An overview of emergent strategy issues. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association*, *19*(6), 424–438. https://doi.org/10.1111/1540-5885.1960424

McMillan, G. S., Narin, F., & Deeds, D. L. (2000). An analysis of the critical role of public science in innovation: The case of biotechnology. *Research Policy*, *29*(1), 1–8. https://doi.org/10.1016/S0048-7333(99)00030-X

Menguc, B., Auh, S., & Yannopoulos, P. (2014). Customer and supplier involvement in design: The moderating role of incremental and radical innovation capability. *Journal of Product Innovation Management*, *31*(2), 313–328. https://doi.org/10.1111/jpim.12097

Meuleman, M., & De Maeseneire, W. (2012). Do R&D subsidies affect SMEs' access to external financing? *Research Policy*, *41*(3), 580–591. https://doi.org/10.1016/j.respol.2012.01.001

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook*. Sage.

Miller, C. C., Cardinal, L. B., & Glick, W. H. (1997). Retrospective reports in organizational research: A reexamination of recent evidence. *Academy of Management Journal*, *40*(1), 189–204. https://doi.org/10.2307/257026

Nag, R., Corley, K. G., & Gioia, D. A. (2007). The intersection of organizational identity, knowledge, and practice: Attempting strategic change via knowledge grafting. *Academy of Management Journal*, *50*(4), 821–847. https://doi.org/10.5465/amj.2007.26279173

Nelson, R. R. (1959). The simple economics of basic scientific research. *Journal of Political Economy*, *67*(3), 297–306. https://doi.org/10.1086/258177

Peng, H., & Liu, Y. (2018). How government subsidies promote the growth of entrepreneurial companies in clean energy industry: An empirical study in China. *Journal of Cleaner Production*, *188*, 508–520. https://doi.org/10.1016/j.jclepro.2018.03.126

Polkinghorne, D. E. (1988). *Narrative knowing and the human sciences*. State University of New York Press.

Radicic, D., & Pugh, G. (2017). R&D programmes, policy mix, and the 'european paradox': Evidence from European SMEs. *Science and Public Policy*, *44*(4), 497–512. https://doi.org/10.1093/scipol/scw077

Söderblom, A., Samuelsson, M., Wiklund, J., & Sandberg, R. (2015). Inside the black box of outcome additionality: Effects of early-stage government subsidies on resource accumulation and new venture performance [Article]. *Research Policy*, *44*(8), 1501–1512. https://doi.org/10.1016/j.respol.2015.05.009

Steinmo, M., & Rasmussen, E. (2016). How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects. *Journal of Business Research*, *69*(3), 1250–1259. http://dx.doi.org/10.1016/j.jbusres.2015.09.006

Szczygielski, K., Grabowski, W., Pamukcu, M. T., & Tandogan, V. S. (2017). Does government support for private innovation matter? Firm-level evidence from two catching-up countries. *Research Policy*, *46*(1), 219–237. https://doi.org/10.1016/j.respol.2016.10.009

Szücs, F. (2018). Research subsidies, industry–university cooperation and innovation. *Research Policy*, *47*(7), 1256–1266. https://doi.org/10.1016/j.respol.2018.04.009

Torregrosa-Hetland, S., Pelkonen, A., Oksanen, J., & Kander, A. (2019). The prevalence of publicly stimulated innovations –A comparison of Finland and Sweden, 1970–2013. *Research Policy*, *48*(6), 1373–1384. https://doi.org/10.1016/j.respol.2019.02.001

Tsai, W. (2001). Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. *Academy of Management Journal*, *44*(5), 996–1004. https://doi.org/10.5465/3069443

Vanino, E., Roper, S., & Becker, B. (2019). Knowledge to money: Assessing the business performance effects of publicly-funded R&D grants. *Research Policy*, *48*(7), 1714–1737. https://doi.org/10.1016/j.respol.2019.04.001

Wang, Y., Li, J., & Furman, J. L. (2017). Firm performance and state innovation funding: Evidence from China's Innofund program. *Research Policy*, *46*(6), 1142–1161. https://doi.org/10.1016/j.respol.2017.05.001

Wanzenböck, I., Scherngell, T., & Fischer, M. M. (2013). How do firm characteristics affect behavioural additionalities of public R&D subsidies? Evidence for the Austrian transport sector. *Technovation*, *33*(2–3), 66–77. https://doi.org/10.1016/j.technovation.2012.11.006

Yi, J., Murphree, M., Meng, S., & Li, S. (2021). The more the merrier? Chinese government R&D subsidies, dependence, and firm innovation performance. *Journal of Product Innovation Management*, *38*(2), 289–310. https://doi.org/10.1111/jpim.12564

Yin, R. K. (1989). *Case study research. Design and methods* (Vol. 5). SAGE Publications Ltd.

Yin, R. K. (2014). *Case study research: Design and methods*. Sage publications.

Zhao, B., & Ziedonis, R. H. (2012). State governments as financiers of technology startups: Implications for firm performance. *SSRN Electronic Journal*. Available at SSRN 2060739. https://doi.org/10.2139/ssrn.2060739 .

Zúñiga-Vicente, J. Á., Alonso-Borrego, C., Forcadell, F. J., & Galán, J. I. (2014). Assesing the effect of public subsidies on firm R&D investment: A survey. *Journal of Economic Surveys*, *28*(1), 36–67. https://doi.org/10.1111/j.1467-6419.2012.00738.x