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The effects of R&D subsidies and publicly performed R&D on business R&D: A survey

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Abstract. This literature review shows that a majority of studies finds complementarity of R&D subsidies and tax credits with private R&D expenditures. A non-negligible minority finds incomplete crowding out. Full crowding out is found only for small parts of the respective samples or small sub-sectors of the economy under consideration. Education R&D and publicly performed R&D stimulate private R&D according to a small literature. We focus on the exceptions from these dominant results. The controversies concern firm size, interaction of policy instruments, and effectiveness of parts of publicly performed R&D. There are important suggestions for future research derived from our literature review: (i) use of dynamic models with adequate time lags, (ii) explaining effects of country and firm heterogeneity.

Keywords: Research & development, business R&D, subsidies, public R&D. JEL code: H25, O38.

1. Introduction

This paper surveys the literature on the effects of public R&D, subsidies and performance, and, to a limited extent, tax incentives on business R&D expenditures. As many articles state that there is no consensus, results are far from homogeneous and there are not automatic effects, the question is where the sources of different outcomes are. There is much less disagreement on the positive effects of tax credits and therefore we focus on R&D subsidies and public performance.

There are several reasons why the literature argues that governments should support R&D. Decisions on research and development activities of private firms suffer from market imperfections, monopoly, knowledge externalities and uninsurable uncertainty (Arrow 1962). All these arguments point to the likely outcome of sub-optimally low R&D expenditures. Closely connected to the uncertainty part of market imperfections, transaction costs also make markets imperfect: (i) in financing of R&D, external funds are more expensive than internal funds for small and start-up firms. Agency costs are relevant, risks have to be compensated, creditors prefer debtors with the lower liquidations costs of other than R&D-intensive firms, and tax systems responding to these issues differ (Hall 2002). (ii) In knowledge transfer processes, there are information search costs (Lundvall and Borãs 2005). Both transaction cost arguments are closely linked to the market imperfection of lack of insurance. They have led to the suggestion that government support could induce improvements, because it is not a priori clear that markets are optimal from the perspective of society. Moreover, governments have to decide on R&D regarding public tasks like defence,

[1]This paper stems from extending work done for European Commission, Expert Group Support of R&I performance and policy analysis under contract number CT-EX2017D315103-101. This survey is biased towards EU countries. Other aspects of focus are discussed in the text. Useful comments from Luc Soete, Bart Verspagen, and participants at meetings of DG RI A4 and A2 (ESIR) are gratefully acknowledged.

environmental issues, health, space and energy, together (with others) called missions (Mazzucato 2018). Private business paid by governments carries out some of them but public research institutions do other parts of mission R&D. Salter and Martin (2001) and Antonelli (2019) critically review the fundamental rationale for R&D support. They suggest that aspects of structural change in research and the accumulation of knowledge and its generating activities should be the target of R&D support.

Private and public R&D in principle may be complements or substitutes in the knowledge perspective because there may be cost reductions, spillovers, and duplications. In addition, private and public R&D compete for researchers in high-skill labour markets (Goolsbee 1998; Wolff and Reinthaler 2008). Market imperfections with strategic interactions (Takalo et al. 2013a), knowledge complementarities and factor market competition, also from policy repercussions from abroad (Soete et al. 2019; Ziesemer 2019), make it difficult to know whether too little or too much public R&D expenditure exist in practice. Empirical economic intuition suggests that there is too much public R&D spending if private R&D is crowded out strongly. If, however, additional tax credits, R&D subsidies and publicly performed R&D encourage private R&D to increase expenditures, this is seen as a social improvement, because private R&D is supposed to be below optimum without policy according to the reasoning indicated above. Moreover, public R&D is under suspicion of being too low because of its link to public goods, limited tax revenues and free rider behaviour. Increases of private and public R&D are therefore by default assumed a social improvement. However, it is far from clear that the design of policies takes all the problems in an adequate way into account and that distortions from purely political motivations are absent.

There are several possible constellations for deviations from an optimum for financing of or investing in public and private R&D. If there is too little public R&D, business R&D may also be too low if they are knowledge or factor-market complements. If there is too little public R&D, this may create interest in doing public R&D, and business R&D may try to fill a part of the gap if they are substitutes. If there is too much public R&D, business R&D could also be too large if they are complements. If there is too much public R&D, business R&D could be too low if they are substitutes. In this latter case, the question is whether a business R&D reduction is larger or smaller than the deviation of public R&D from its optimum. This determines whether total R&D is larger or smaller than the optimum.[2] The question of this paper therefore is whether public R&D enhances private R&D spending according to the empirical literature.

In these considerations, it can be useful to distinguish between financing and carrying out (performing) R&D. Concerning financing, the literature distinguishes between tax credits and R&D subsidies (sometimes in the special forms of start-up facilities and funds for small and medium enterprises, SMEs). Under tax credits, which are in principle available for all firms, having spent money on R&D is a pre-condition for getting tax reduction and therefore eligible expenditures cannot be withdrawn (Spengel et al. 2017). Therefore, we touch upon this literature only cursorily.[3]

[2] Radicic (2014) gives a more extensive explanation of these cases.
[3] We indicate below that the literature analysing the joint effects of several instruments is small. We do not discuss tax-subsidy-law specialties such as incremental and gradual tax schemes, patent boxes, regional R&D policies, support of cooperation, compliance costs and other special areas, because their success indicators differ too much. Of course, the choice of the adequate instruments has an impact on the effectiveness of the

However, rules for tax credits may be linked to revenue, size and R&D of firms, and rules and problems of timing (see Mohnen and Lokshin 2010; Appelt et al. 2016). In general, the literature assumes that these limitations are weaker for tax credit systems than for subsidies linked to government plans, programs, projects, and missions. These circumstances together make it possible that private R&D expenditures can be reduced to some extent, but more likely so through subsidies than through tax credits. On the other hand, an advantage of subsidies is that they relax credit constraints.[4] There are some links between subsidies and tax credits and therefore we need to look at the tax credit literature also a little bit.[5]

We do not include organisational (neither internal nor external) and behavioural[6] studies, which can fill books and articles on their own, which should be linked to the basic related science disciplines. Similarly, low-interest credit requires detailed argumentation on treatment of heterogeneity of firms by creditors, again requiring a survey on its own linked to the specificities of capital markets. We omit studies on special sectors, such as energy and agriculture, because results are related to traditional exceptional policies such as production or input subsidies. A literature survey in section 2 focusses mainly on the question as to what triggers private R&D, funding and performance, and section 3 leads to suggestions for improvement through additional research using dynamic methods.

2 Literature survey: The impact of R&D subsidies on private R&D expenditure and innovation related measures

This section derives from the literature that tax credits, R&D subsidies and public R&D performance all lead to enhanced total R&D either through triggering additional private R&D or because of incomplete crowding out. The emphasis of the section therefore is on understanding the limits of this general line.

The gross R&D expenditures of a country are sub-divided into those of business and non-business. In doing so, one has to decide whether one wants to look at the funding irrespective of who is doing the research or at the performance irrespective of who is funding. Most of the literature is looking at the effects of government funding on business funding with the more or less explicit question whether or not too much government money is going to public R&D? An answer to this question should not only depend on the question of crowding out private R&D financing but also on the question of the effects of public R&D performance on business R&D expenditure. Therefore, we also look at literature on public R&D performance. In section 2.1, we look briefly at effects of government funding through tax credits on business funding for R&D when subsidies are also an important instrument. In section 2.2, we summarise the bulk of the literature, which looks at the effects of government funding through R&D subsidies on business funding of R&D. The literature on the

policies, but each instrument is generating a literature on its own (see Hall 2019; Bloom et al. 2019; Pöschel 2019).

[4] Even without credit constraints, subsidies should in principle lead to cost reductions and more activity unless projects are lumpy and the number of projects going from unprofitable to profitable is low.

[5] The instruments are discussed more extensively in Montmartin and Herrera (2015). Negassi and Sattin (2014) provide a meta study. The interaction between tax credit and credit constraints is analysed by Kasahara et al. (2014).

[6] See Neicu (2016a); Neicu et al. (2016).

effects of government R&D performance on business R&D is much smaller and we summarise it in section 2.3; showing that it requires more research is the main purpose of this paper. Section 3 briefly summarises the results of the literature and derives important aspects for future research from it.

Empirical studies go back to the 1950s (García-Quevedo 2004). They make statements regarding complementarity and substitutability or statistical insignificance, but conclusions on the degree of substitutability and complementarity are sometimes left to the reader.[7] This is important though, because, e.g., a 10% increase of public R&D may be responded to by a 1% reduction of private R&D, which, at about equal size of public and private R&D, would still imply a large overall increase, with business leaving some public tasks to the government rather than becoming inactive. If , instead, business reduces R&D expenditure by the same amount that the government spends or even more we would have complete crowding out. A third case of course is that firms also spend more and we have complementarity. We summarise the literature in Tables 1 and 2. The R&D financing literature can be divided into two branches: effects of R&D tax incentives and R&D subsidies. We focus more on the latter and deal with tax credits only briefly in section 2.1.

Table 1 lists literature from surveys, meta-studies and panel studies covering many countries and thereby many institutional systems. We do this in chronological order in order to see whether over time there is progress in the sense of getting clearer results, starting with surveys from this millennium. Column 1 denotes the author(s) and year of the study. Column 2 indicates whether it is a survey, a meta study or a panel study. Columns 4 and 5, sometimes merged, give the major result in one sentence only, and some additional information or comments. We mostly do not repeat the information of columns 4 and 5 in the text, because the literature is large and the article is already long.

The sub-sequent text focusses on the problems and the structure of the results in order to go from mere description to a structural understanding of the state of the art.

Table 1 Surveys, Meta studies and Country Panel Regressions (chronological order)

Author(s) (year)	*Study type*	*level*	*Result*	*Remarks*
Hall, van Reenen 2000	*Survey*	OECD tax systems: "a dollar in tax credit for R&D stimulates a dollar of additional R&D".		
Klette et al. 2000	survey	Complementary relationship between public and private R&D for selected studies		
David et al. 2000	Survey	33 studies	Favour complementarity; a third of the 33 studies under review report substitution effects	
Guellec, van Pottelsberghe dlP 2003	Panel regression	11 OECD countries	Inverted u-shape; substitution for subsidies >20%	
José García-Quevedo 2004	Meta-study of 39 studies	74 results for firms, sectors, countries	ambiguous; more than half of the studies has significantly positive effects	

[7] Bohnstedt (2014) formulates the problem in terms of a theoretical Melitz framework.

Jaumotte & Pain 2005	Panel regression,	19 OECD countries	"… an expansion in publicly funded and performed R&D will raise the real wages of researchers employed in the private sector" (j)
Khan, Luintel 2006	Panel regression	16 OECD countries	Negative interaction effect of public and business. Total effect of public R&D positive.
Falk 2006	Panel regression	21 OECD countries	Public does not affect business R&D … but university R&D does
Coccia 2010	panel	31 EU countries, 10-12 years	Public and private R&D are complementary.
Cincera et al. 2011	Stochastic frontier and Data Env Anal	OECD	Positive heterogeneous effect
Lee 2011	firm data	nine industries in six countries (g)	"complementarity effect on private R&D for firms with low technological competence, for firms in industries with high technological opportunities and for firms facing intense market competition"
Czarnitzki, Lopes Bento 2012	cross-country micro data	Belgium, Germany, Luxembourg and Spain	'firms would have invested significantly less if they would not have received subsidies' but not in South Africa; (e)
Correa et al. 2013	meta study	37 studies 2004-2011	Significantly positive additionality, coefficient 0.166-0.252.
Zúñiga-Vicente et al. 2014	survey	firm level	Positive effects where time lags and credit constraints are taken into account.
CPB 2014	multi country	tax system	Econometrically more rigorous studies find positive effects of less than one Euro from 1 additional Euro tax reduction.
Radicic 2014	broad survey	all levels	very little full crowding out indications
Czarnitzki et al. 2014	Finland, Germany, Netherlands	firm level projects	highest profits, spillovers and application costs in German projects
Becker 2015	survey	mainly manufacturing firms	Positive effects in studies on (a). In the pre-2000 literature … tax credits have a significant positive effect on R&D expenditure, … considerable variation in the findings … . (b), (c), (d); later better econometrics on selection effects.
Montmartin, Herrera 2015	25 OECD countries	Macro	Publicly executed R&D has a positive effect; public support a negative effect and tax credit a positive effect.
Dimos, Pugh	meta regression	52 studies	No crowding out, (i); no substantial

2016	analysis	published after 2000	additionality in patents and new products, but increasing over time.
Radicic, Pugh 2017	EU 28	National and EU programs for SME	Complete crowding out of output additionality from EU programs not rejected but avoided by national programs; no crowding out of input additionality.
Aristei et al. 2017	Largest EU countries, 2007-2009	Manufacturing firms	Positive effect of R&D subsidies; hypothesis of full crowding-out is rejected in all countries; no additionality from firms, (f). Subsidy effectiveness is increasing over time.
Deloitte 2017	regressions for panels: OECD-17 (G7, Non G7); OECD-17+EU+ICL; 7EU+CHL+ISR	Country panels	… 1 % yields 0.2% across all samples with the exception of G7. Positive effect of education R&D.
Beck et al. 2017	Survey	firms	Positive relation with private R&D; no crowding out;
Petrin 2018	survey (h)	EU, OECD, China, Taiwan	complementarity; positive but modest innovation effects; only one indication of complete crowding out in Radicic/Pugh 2017
Van Elk et al. 2019	OECD	Country panel	Insignificant effects under panel homogeneity turn more positive when interaction effects allow for heterogeneity.

(a) Denmark (Bloch and Graversen 2012);
Finland (but not Germany patenting activities) (Czarnitzki *et al.* (2007), mainly small and medium firms (Hyytinen & Toivanen 2005);
Flanders (Aerts and Schmidt 2008);
France, reject crowding out, public subsidies on average increase private R&D (Duguet 2004);
Germany (Aerts and Schmidt 2008, Czarnitzki and Hussinger 2004, Hussinger 2008) (more East than West (Czarnitzki and Licht 2006));
Ireland, inverted u-shape (Görg and Strobl 2007);
Israel (Lach 2002) (not for large but for small firms, with lag);
Italy, (Carboni 2011) rejects crowding out;
Norway improved policy: pre-2000 none (Klette and Møen 2012), post-2000 additionality (Henningsen *et al.* 2015)
Spain (mainly participation effect (González *et al*. 2005); low tech (González, Pazó 2008));
Turkey (Özcelik and Taymaz 2008)
UK: only low tech, high tech substitute (Becker and Hall 2013)

(b) "More recent literature observes a shift away from the earlier findings that public subsidies often crowd-out private R&D to finding that subsidies typically stimulate private R&D."

(c) "University research, high-skilled human capital, and R&D cooperation also typically increase private R&D."

(d) One policy conclusion that can be drawn from all of these studies is that fiscal measures that reduce the user cost may be expected to increase private R&D expenditure. Overall, the average negative elasticity across the various studies appears to be around unity.
(e) 'Governments could foster R&D activities by extending innovation policies to currently not supported firms. … Our analysis does not uncover any systematic misallocation of public funding for the countries under review'.
(f) R&D subsidies 'thwarted the reduction of firm R&D efforts in the aftermath of economic crisis'.
(g) Literature on cross-industry-cross-country studies could be extended or abandoned.
(h) This very recent survey inevitably has overlap with ours. It is also more interested in tax credits and other output measures.
(i) This result is seen as lower bound in the literature (Beck et al. 2017).
(j) "An increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%." (Jaumotte and Pain 2005, p.38, for the performance definition of R&D). "… an increase of 1 standard deviation in the share of non-business R&D funded by the private sector (an increase of 1.4 percentage points for the average economy) will eventually raise business sector R&D by over 8% and total patenting by close to 2½ per cent …" (Jaumotte and Pain 2005, p.39, for the financing definition of R&D).

2.1 The effects of tax credits

In this sub-section, we briefly indicate that tax credits have positive effects on private R&D expenditures already in the short run. This study is brief on tax credits as they are relatively non-controversial except for the details of tax laws (CPB 2014), but of course, research is going on. [8] Firms obtain tax credit only for R&D expenditures really made. The question is whether there is a positive or no effect, but there cannot be a negative effect, conceptually, unless one finds reasons to cut R&D expenditures, which are not tax deductible, or institutional arrangements not inherently related to the concept of the tax credit (see above). Hall and van Reenen (2000) report a clearly positive effect. Jaumotte and Pain (2005) summarise as follows: "More generous tax reliefs for R&D are more frequently found to have a positive impact on the amounts of both R&D and patenting than higher levels of direct funding". CPB (2014) summarises as follows: "The vast majority of studies surveyed in this report conclude that R&D tax credits are effective in stimulating investment in R&D. The estimates of the size of this effect are widely diverging. They are not always comparable across countries due to differences in methodology. Studies that are more rigorous find that one euro of foregone tax revenue on R&D tax credits raises expenditure on R&D by less than one euro."[9] In a survey, Becker (2015) reports that more recently even more studies find a clearly positive effect although with a great variation in the details of the results. Beck et al. (2017) conclude, "The bottom line here is that there is a consensus in the empirical literature that tax credits have a significantly

[8] A more in-depth treatment requires going deeply into the national tax system, which is beyond the scope of this paper.
[9] See references there, which point to microeconomic studies. In addition, Finger (2008) finds a similar result. Guceri (2018) finds a positive impact on the number of researchers controlling for relabeling. Corchuelo and Martínez-Ros (2010) point out that mainly large firms use tax credits and have statistically significant effects in Spain.

positive short-run effect on private R&D investment. By contrast, direct subsidies do not have short-run effects but have positive medium-run impacts." Rao (2016) finds positive short and long run effects for the USA 1981-91 using a new strategy to deal with simultaneity. Thomson (2017) points out that his estimates give a much higher elasticity than earlier literature.

2.2 The effects of R&D subsidies

In this sub-section, we report from the literature that there is no complete crowding out of private R&D through R&D subsidies. Crowding out is either incomplete or additional private R&D expenditures are triggered. R&D subsidies therefore enhance total R&D expenditures. For R&D subsidies, we summarise the literature as follows.[10] The survey of Klette et al. (2000) finds complementarity between public and private R&D as one would expect it, dynamically, from Nelson (1959) and endogenous growth models (Shell 1967; Ziesemer 1991, 1995; Antonelli 2019). David et al. (2000) have pointed out that articles published in the 1990s ignore the endogeneity problem.[11] Therefore, the literature in Table 1 mostly focusses on literature that is more recent. As Becker (2015) points out, literature that is more recent often finds positive effects. This holds for

- performance and funding data (Jaumotte and Pain 2005; see note (j) to Table 1); and in particular

- for university R&D (Falk 2006),

- when time lags (Lach 2002, Toole 2007, Herrera and Ibarra 2010, Zúñiga-Vicente et al. 2014, Soete et al. 2019) and

- credit constraints are taken into account (Meuleman, De Maeseneire 2012; Zúñiga-Vicente et al. 2014[12]),

also for Turkey (Özcelik and Taymaz 2008), but not so for South Africa (Czarnitzki and Lopes Bento 2012).[13] In line with this, García-Quevedo (2004) finds ambiguous results in the mostly older literature. During the crisis period 2007-2009, subsidies just prevent reduction of R&D (Aristei et al. 2017; see also below Hud and Hussinger (2015) and Barajas et al. (2017), all indicating similar reactions during the crisis). Becker (2015) attributes the more positive results to advances in econometrics, mainly consideration of selection effects. Therefore, our intention to survey literature does not go into articles of the previous millennium.[14]

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[10] We do not reinvestigate the surveys, but rather limit ourselves to taking their results and putting a couple of interpreting comments. This biases the number of studies towards more recent ones on purpose, as Cerulli (2010) and Becker (2015) point to the importance of using more sophisticated methods. By implication, studies, which we report in connection with surveys in Table 1, mostly do not appear as country-specific studies in Table 2.

[11] Having endogeneity does not necessarily mean that there is a large bias (see Nakamura and Nakamura 1998 for the econometrics). In addition, when lags are taken into account the issue hardly matters (Lee 2011).

[12] As lags should always play a role, these authors' summary of only 60% of the studies finding a positive effect suggests that lags have often not been taken into account. Grilli et al. (2018), following the pessimistic interpretation of Zúñiga-Vicente et al. (2014), ignore the much more positive survey of Becker (2015).

[13] We consider emerging economies only when they are related in some way to the EU or the related literature.

[14] Diamond (1999), besides the older surveys mentioned here, is a rich source for older literature.

We focus now on the exceptions and limits to positive results related to Table 1 and its notes, with some references to Table 2 below with the single-country studies. Guellec and van Pottelsberghe (2003) find negative effects when subsidies go beyond 20% of the R&D expenditures but positive effects at lower rates. Görg and Strobl (2007) also find an inverted u-shape for firm level data for Ireland, Dai and Cheng (2015) do so for China's private R&D, and Ugur and Trushin (2018) for the UK.

Effects are larger for small and medium size firms than for large firms (Lach 2002 for Israel; Hyytinen and Toivanen 2005 for Finland; and others presented in Table 2 below). This suggests that large firms have sufficiently large profits and do not depend on credit for their R&D investments; the literature emphasises credit market imperfections and appropriability problems, but imperfect competition may relax or even avoid credit constraints through sufficiently high profits. R&D subsidies are linked to profits by models of Gonzalez et al. (2005), Arqué-Castells and Mohnen (2015) and Takalo et al. (2013a, 2017[15]). R&D subsidies may help getting beyond thresholds for continuation and entry (Arqué-Castells and Mohnen 2015). Subsidies lead to more bank credit in some countries (Hottenrott et al. 2017b). Takalo and Tanayama (2010) find that subsidies relax the credit constraint, improve the screening, and provide signals to financiers. However, whereas informational signals may work, there is not a general certification effect, although subsidies work more strongly under credit constraints (Howell 2017).

Participation is enhanced in Spain (González *et al*. 2005), and effects are stronger for low tech firms in Spain (González, Pazó 2008) and the UK, where high tech firms substitute R&D expenditures leading to statistically insignificant effects (Becker and Hall 2013). A recent multi-country study of Deloitte (2017) reports positive effects for all sub-samples but the G7. Further dis-aggregation seems necessary in order to take into account the heterogeneity among the G7 countries. Zúñiga-Vicente et al. (2014) point out that there is a lack and need of dynamic considerations. Soete et al. (2019) share this view and use the vector-error-correction method for the Netherlands. Public R&D then has strongly positive effects, which are weaker if other countries also enhance public R&D.

In Table 2, we list country-specific studies in alphabetic order of the country names in column 2 as we assume that readers prefer having papers on the same country in one place. We list only one very recent study on China (Dai and Cheng 2015), which points to similar relations as other literature, whereas other literature emphasises specific Chinese institutions, leading to a more specialised literature. We include some recent studies on the USA because policy ideas sometimes spill over from the USA to the EU and so do research ideas.

Most studies show complementary effects either directly in terms of money spent or indirectly in terms of additional patents, new products, or other effects clearly related to R&D,[16] that would not have been achieved under private reduction of R&D spending (Cohen et al 2002; Jaffe and Le 2015; Azoulay et al 2019; Buchmann and Kaiser 2019). Therefore, we focus again on the exceptions.

[15] "Low profit margins (or limited availability of internal funds) seem to be an obstacle for R&D performance…".

[16] We will not survey the literature where the dependent variables are macroeconomic or production related firm employment (see Vanino et al. (2019), GDP per capita or productivity (see Donselaar and Koopmans 2016; Aguiar and Gagnepain 2017). Innovation indicators will be mentioned only as an exception.

Table 2 Country level studies (alphabetic order by country name)

Author(s) (year)	*Country*	*level*	*Result: effect of additional public R&D*	*remarks*
Bakhtiari, Breunig 2018	*Australia*	*Industrial firms*	*R&D expenditure by academia has a positive influence on a firm's own R&D expenditure …*	*… within state boundaries. Government bodies outside academia have no positive effect.*
Widmann 2017	Austria	firms	A government research grant increases the propensity to file a patent application with the European Patent Office within 4 years by around 10 percentage points. Stronger effects appear for established firms of advanced age.	
Meuleman, De Maeseneire 2012	Belgium	1107 subsidy requests	"obtaining an R&D subsidy provides a positive signal about SME quality and results in better access to long-term debt"	
Hottenrott, Lopes-Bento 2014	Belgium	SME	R&D subsidies trigger R&D spending and marketable innovations, especially from firms in international collaborations.	
Hottenrott et al. 2017a	Belgium	firms	… a positive effect on R&D spending…	… increasing with market failure
Neicu 2016b	Belgium	firms	Subsidies have positive effects on private R&D spending only in the presence of tax credits…	… tax credits and subsidies are complements
Neicu et al. 2016	Belgium	Firms …	…apply tax credits more to research than to development when receiving subsidies …	… accelerate and scale up projects
Czarnitzki, Delanote 2017	Belgium	firms	Positive effects confirmed …	… but no new sales.
Bérubé, Mohnen 2009	Canada	Plant level	Grants lead to more new products …	… in the presence of tax credits (e)
Dai, Cheng 2015	China	firms	inverted-U correlation with private R&D investment	public subsidies follow an S-shaped relationship with the firm's total R&D;
Radas et al. 2015	Croatia	SME	R&D subsidies affect innovation indicators	tax incentives affect only R&D employment
Čadil et al. 2018	Czech Republic	SME	Positive impact on personnel expenditure.	Negative impact on economic criteria.
Dvouletý et al. 2018	Czech Republic	firms	incubated firms reported on average lower values of personnel costs	

Kaiser 2006	Denmark	firms	"Positive and statistically weakly significant effects of R&D subsidisation on R&D intensity." Food industry receives most subsidies.	
Kaiser, Kuhn 2012	Denmark	Joint ventures	Quick effects on patenting and employment, but not sales or productivity. No effects for large firms.	
Hünermund, Czarnitzki 2019	Europe	SME	No treatment effects on patents from Eurostars program	
Hünermund, Czarnitzki 2016	(pan-) European	SME	VCP grants; no average effect on growth, but higher effect with project quality.	
Takalo et al. 2013b	Finland	Project level	Targeted subsidies have social rate of return between 30 and 50%.	
Einiö 2014	Finland	Firms	positive impacts on R&D investment, employment, and sales from ERDF funding to regions.	
Czarnitzki, Lopes-Bento 2013	Flanders	Firms	R&D subsidies, no full crowding out. Effects stable over time. R&D jobs are created.	
Serrano-Velarde 2008	France	Firms, ANVAR program	Private R&D investment increases for small and decreases for large firms	
Bedu, van der Stocken 2015	France, Aquitaine		R&D subsidies trigger business R&D	
Marino et al. 2016	France	Firms	… additionality only for a few top companies (subsidies > €10mill.); substitution for others (€145k-1.8mill); significant substitution for doses €20k-55k. Worse results after reform, 2004-2009.	Larger doses have no weaker effect, in contrast to other literature. Substitution is defined as negative growth rate differences from treatment.
Montmartin et al. 2018	France	Firms in NUTS3 regions	Only national subsidies have crowding-in effects…	… because of negative spatial dependence among regions.
Czarnitzki, Fier 2002	Germany	service sector firm level	complete crowding out rejected	
Almus, Czarnitzki 2003	Germany, East	Firms	firms increase their innovation activities …	… by about four percentage points compared to no subsidies
Czarnitzki, Toole 2007	Germany	Manufacturing firm	R&D subsidies reduce the uncertainty effect of R&D investment	
Reinkowski et al. 2010	Germany, East	Firms, 2003	"subsidised firms indeed show a higher level of R&D intensity and a higher probability for patent application compared to non-subsidised firms …2003"	"highest increase in terms of R&D intensity is estimated for micro businesses with up to 10 employees"
Fornahl 2011	Germany	Biotech firms	R&D subsidies focusing	… while subsidies

			on single firms do not increase patent intensity, …	which are granted to joint R&D projects do so to a certain extent.
Alecke et al. 2012	Germany, East	SME	Positive effect on R&D intensity.	
Hud, Hussinger 2015	Germany	Firms 2006-2010	Positive effect except … … crowding out in 2009; 2010 positive but smaller effect than before crisis	
Czarnitzki, Delanote 2015	Germany	CIS firm panel	No complete crowding out; strongest effects on high-tech firms.	
Czarnitzki, Hussinger 2018	Germany	Firm level, 1992-2000	publicly induced R&D shows a positive effect on patent outcome	
Plank, Doblinger 2018	Germany	firms energy R&D projects	subsidies enhance value of patents …	… but not the number of citations
Hottenrott et al. 2017b	Germany 2005-2009	firm level	Grants make bank loans more likely and larger…	… more so in information opaque sectors
Abdul Basit et al. 2018	Germany	Service firms	Subsidies increase marketing and organisational innovations and probability of applying for a copyright	
Koehler, Peters 2017	Germany	firm level	patent application from subsidised firms have higher private value …	… than from firms not subsidised
Koehler 2018	Germany, 1994-2011	firms in thematic programs	positive effects on welfare and profits …	… as large as those from foreign spillovers
Comin et al. 2018	Germany	Firms	Interaction with Fraunhofer Society increases human capital hirings, productivity, …	… more in generation than implementation of technologies.
Buchmann, Kaiser 2019	Germany	Biotech industry	Increased patent output …	… in Individual and collaborative research
Parisi, Sembenelli 2003	Italy	726 firms over the 1992–1997	Subsidy-investment elasticity is -1.5-(-1.77)	
Hall et al. 2009	Italy	7375 manufacturing firms	Receiving a subsidy leads to higher R&D intensity; more for high tech firms, which perhaps receive higher subsidies	
Colombo et al. 2011	Italy	247 Italian-owner-managed NTBFs in manufacturing and services	positive effects if selective expert schemes certify quality …	… but not for automatic schemes
Cerulli, Poti 2012	Italy	Firms	Overall positive effects mainly through large firms …	… small firms often show crowding out
Bronzini, Iachini 2014	Italy, North	Firms	Small firm invest more, large firms do not.	Competition based on scores.
Bronzini, Piselli	Italy, North	Firms	1 patent for grants of	More markedly for

2016			€206k-310k	small firms.
Mariani, Mealli 2017	Italy, Tuscany	Firms	Encouraged non-R&D firms to do R&D and upskill	
Ibeigi 2017	Italy, Trento	firms, local R&D program	some crowding out	also additional spillovers
Aiello et al. 2017	Italy	SMEs	Supported firms have same patenting but more R&D spending.	
Koga 2015	Japan	223 high-tech start ups	Publicly funded R&D promotes private R&D and is complement.	
Ziesemer 2019	Japan	Macro	Cumulated non-business R&D capital stock has a positive impact on business R&D capital stock; GBOARD capital stock has no impact.	
Soete et al. 2019	Netherlands	Macro	… higher business R&D and time varying gains for decennia; high internal rates of return	Scenarios without and with firm R&D shocks and symmetric foreign policy actions.
Clausen 2009	Norway	Firm level	R&D subsidies stimulate research investment and quality of researchers, …	… reduce the budget for development, but not for innovation other than R&D
Grabińska, Stabryła-Chudzio 2017	Poland	Country	Substitution; incomplete crowding out.	Pearson correlation coefficient of 0.86
Busom 2000	Spain	Firm level	… induces more effort…	For 30% of the participants full crowding out cannot be excluded.
González et al. 2005	Spain	Firms	R&D subsidies enhance R&D with unit elasticity. Some firms would stop R&D without subsidies.	Most subsidies go to firms, which would do R&D anyway.
Gelabert et al. 2009	Spain	Firm level	effect of public support for R&D is three times larger for those firms reporting a level of appropriability below the median	
Herrera, Ibarra 2010	Spain	Firm level	R&D subsidies have positive effect on innovation inputs; time lags are important.	Larger firms get more but have smaller effect than SMEs
Romero-Jordán et al. 2014	Spain	SMEs	Tax credits have partial crowding out …	… of negative zero when some receive also public grants
Arqué-Castells, Mohnen 2015	Spain	Manufacturing firms	'one-shot trigger subsidies cause a substantial increase in … share of R&D firms and	'This effect shows persistence over time, but totally fades away after seven years'

			average R&D expenditures.’	
Huergo, Moreno 2017	Spain	4407 firms …	higher participation; hypothesis of complete crowding out rejected …	… but not for large firms. European loans more effective.
Barajas et al. 2017	Spain	firm level (CIS)	Positive effect of public support on participation and all intensities also during crisis.	Lower impact during crisis, in particular fixed R&D capital. Shift from process to product innovation.
Alvarez-Ayuso 2018	Spain	237 firms	Public support works well for firms with continuous investment. Tax credits are suitable for boosting investment;	especial incremental tax credit at low investment levels
Haskel et al. 2014	UK	Industry	Universities get more private money if they had more public money earlier.	(b)
Economic Insight 2015	UK; with survey	Macro and micro	a 1% increase in public expenditure on R&D will lead to between a 0.48% and 0.68% increase in private expenditure on R&D.	No time trend in control variables? (a)
Sussex et al. 2016	UK	ten disease areas for the government, charity and private sectors	A 1 % increase in public sector expenditure is associated in the best-fit model with a 0.68% increase in private sector expenditure.	Biomedical and health R&D expenditure; 44% of the effect within one year.
Ugur, Trushin 2018	UK	43650 R&D active firms	Inverted u-shape effect of subsidies on R&D …	… investment and employment, privately funded
Wallsten 2000	USA	Firms in SBIR	One-to-one crowding out;	Cutting back avoided?
Cohen et al. 2002	USA	manufacturing	*An increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%.*	the influence of public research on industrial R&D is disproportionately greater for larger firms as well as start-ups.

Toole 2007	USA	Biomedical	*Research by universities and non-profit organisations stimulates industry investment.*	Time-series analysis for seven medical classes; strong role of time lags.
Azoulay et al. 2019	USA	Pharmaceutical and biotech firms (d)	*a $10 million boost in NIH funding leads to a net increase of 2.7 patents*	Indirect evidence of limited withdrawal, if any.
Rao 2016	USA	Tax credit 1981-1991	*Positive effects on expenditure in short and long run*	With adjustment costs
Lanahan et al. 2016	USA	Research fields at U.S. doctoral granting institutions	A 1% increase in federal research spending induces … a 0.468% increase in private research funding.	
Lanahan 2016	USA	US firms	State Match Program enhances chances getting SBIR support	
Giga et al. 2016	USA	NASA SBIR	firms with 1-5 employees with SBIR awards are twice as likely to produce patents; and generate twice as many patents;	the program does not show the same effect for larger firms (6 - 500 employees).
Corredoira et al. 2016	USA	Firms	federal funds affect rate and direction of inventive activity according to citation analysis	
Ngo, Stanfield 2017	USA	Peers and non-peers of government dependent (gd) firms	only firms that compete directly with gd firms contract investment in R&D; net reduction in industry R&D …	… caused by incentives for managers in real earnings management. (c)
Howell 2017	USA	US firms	no crowding out; stronger effects under credit constraints, not explained through certification effect.	Firms subsequently attract venture capital.
Gaster 2017	USA	SBIR/STTR	Total investment in SBIR/STTR of $6.25 billion generated; total revenues from products based on SBIR/STTR technologies of $28.9 billion. $8.8 billion in total taxes generated – more than the cost of the program. (f)	
Aysun, Kabukcuoglu 2017	USA	US firms	grants and subsidies reduce their dependence on external finance, their share of R&D spending increases (decreases) during a credit tightening (easing)	

(a) Commissioned by UK Dep BIS. The book has a long literature review and concludes: "The papers do generally find a positive relationship between public sector and private sector funding and the estimates tend to be between zero and one. This, however, is a relatively large range." Note that this range excludes even partial crowding out.

(b) Commissioned by CAMPAIGN FOR SCIENCE AND ENGINEERING.
(c) "government-dependent firms feature in a wide array of industries."
(d) Literature on single industries is limited here.
(e) We do not include tax credit papers in Table 2, unless papers combine them with other relevant aspects.
(f) referring to TechLink.

Many studies have emphasised that there is no consensus on the effect of R&D subsidies. The reason seems to be that heterogeneity prevents us from drawing simple conclusions (Ugur and Trushin 2018). When studies differentiate the effects according to certain characteristics, full crowding out is found only at the extreme end or part of the spectrum of the related distributions (Radicic 2014; Petrin 2018). Examples are, alternatively or jointly,

- picking-the-winner selection procedures, single programs and projects in a special social context, large grants or subsidies above a certain threshold;
- very small or very large firms, a certain percentage of the firms, firms in weak regions, firms or sectors with low knowledge intensity, or
- the highest level of appropriability, high or low product market uncertainty, medium and/or high tech sectors.[17]
- certain years, for example with crisis.

These parts of the sample are mostly small compared to the whole group of firms in a country. We can categorise these aspects into those of (i) programs, projects[18] and selection procedures for the subsidy allocation, (ii) firm characteristics of the subsidy recipients, (iii) markets and sectors for the R&D outcome, and (iv) specific periods.

There is only one recent study after the early ones by Wallsten (2000) that suggests complete crowding out where it remains unclear though how large the share of the US economy is for which this holds true (Ngo and Stanfield (2017).[19] The argument for the US is that some firms are government dependent in terms of sales. The payment by the government includes R&D subsidies. Thirteen percent of all firms depend persistently on governments, on average for 11 years. They benefit from discretionary budget authority (DBA) meaning that US R&D expenditures are sub-parts of those of others labels. Competing firms who loose on government contracts fear losses, which would lead to lower salaries for managers. Therefore, mangers cut down R&D expenditure because of special incentives to keep short-term profits high. In theoretical terms, in this case governments

[17] We do not go into the details of the choice of econometric methods methods. See Hujer and Radic (2004) on sample selection and footnote 9 above on endogeneity. Møen and Thorsen (2017) discuss econometric reasons for publication bias.
[18] See Vanino et al. (2019)
[19] A different special case leading to a different literature is Catozzella and Vivarelli (2011). Whereas the literature tests for input or output additionality, they test for an increase in the sales/expenditure ratio, requiring that the numerator increases more than the denominator. Thus, even if input and output additionality are given, the criterion may not be fulfilled. Claiming an increase seems to be equivalent to requesting increasing returns to scale or profit rates. If actors do not have it, they fail. It seems more adequate to have yardsticks of policy evaluation, which allow also for constant and decreasing returns to scale and zero profits, because Graves and Langowitz (1996) and Coccia (2009) favour decreasing returns. Theoretically, increasing returns to scale or increasing profit rates lead to world monopoly in R&D.

introduce discrimination intentionally, which can be seen as creation of a distortion, which leads to extreme management reactions in a specific agency setting, leading to a more than proportional reduction.

The result of stronger effects in small firms is confirmed for

- Danish joint ventures (Kaiser and Kuhn 2012),
- Italy, North (Bronzini, Iachini 2014; Bronzini and Piselli 2016),
- Spain: weaker effects in large firms and more overall participation (Herrera and Ibarra 2010; Huergo and Moreno 2017; Barajas et al. 2017) and
- weak effects for large firms in a French program with crowding out (Serrano-Velarde 2008).

Regarding large firms, the opposite is suggested for the US (Cohen et al. (2002), Italy (Cerulli and Potì 2012) and France (Marino et al. 2016).

Subsidies in the presence of tax credits – a combination of the two aspects sub-dividing the literature - lead to more new products in Canadian plants (Bérubé and Mohnen 2009), no crowding out in Spanish SMEs in Romero-Jordán et al. (2014), but crowding out cannot be ruled out for 30% of the sample of Spanish firms in Busom (2000). Montmartin and Herrera (2015) find a negative impact of subsidies together with a positive one of tax credits and publicly performed R&D for a macro-panel of 25 OECD countries. More recent evaluations by Huergo and Moreno (2016) and Barajas et al. (2017) find a low effect for large Spanish firms but exclude complete crowding out. Other sources do not have an impact on the effects of R&D subsidies in Flanders (Czarnitzki and Lopes-Bento 2013). Busom et al. (2014) argue that tax credits and subsidies are imperfect substitutes for Spanish firms. Radas et al. (2015) find that subsidies are more important than tax credits for SMEs in Croatia. In contrast, Neicu (2016b) suggests that subsidies are only effective in the presence of tax credits in Belgium. Dumont (2017) suggests that they are weakening each other's effects for Belgium's firms. Neicu et al. (2016) show that users of tax credits focus more on research then development when they receive subsidies. Guellec and van Pottelsberghe de la Potterie (2003) and Montmartin and Herrera (2015) find that tax credits and R&D subsidies are substitutes in a study of 17 and 25 OECD countries respectively; there are spillovers to neighbouring countries. Mulligan et al. (2017) offer a conceptual framework to evaluate policy mixes.

Besides market failure, there may also be government failure. Buigues and Sekkat (2011) collect a number of related case studies. In the presence of market and government failure, institutional learning is of importance. Policy learning plays a role in the case of Norway, where no effects are found pre-2000 (Klette and Møen 2012) but positive effects post-2000 (Henningsen *et al.* 2015). Moreover, much research has been done on the question whether firms with more additionality have received most of the subsidies. Lööf and Heshmati (2005) report studies from several countries where this was not the case. Kaiser and Kuhn (2012) suggest reconsidering the fact that large firms get most of the subsidies. Wanzenböck et al. (2013) suggest, "Attention of public support should be shifted to smaller, technologically specialised firms with lower R&D experience". Mohnen (2018) discusses evidence based policy and concludes "The evidence suggests that the impact of R&D tax incentives in terms of stimulating business R&D tends to be stronger for young companies and SMEs, and hence targeting young innovative companies in particular could be considered a valid option." In line with these articles, Czarnitzki and Delanote (2015) argue, that the current policy focus on small, young, high-tech firm types is not ineffective.[20] Governments may have learned from this in some countries and cause more positive results. If government learning is limited, Matthew effects may produce self-perpetuating dynamics reinforcing inefficient policy strategies (Antonelli and Crespi 2013). Moreover, there seems to be no uniquely best policy instrument when situations of countries and firms are heterogeneous; crucial aspects are credit constraints and productivity of firms, which in turn may vary between sectors (Haapanen et al. 2014).

2.3 Publicly performed R&D and its effects on privately performed R&D

Articles dealing with this issue suggest predominantly that publicly performed R&D stimulates private R&D. Regarding the question whether publicly performed (rather than financed) R&D triggers private R&D our tables contain some results.[21] Cohen et al. (2002) show for US manufacturing firms that an increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%. The influence of public research on industrial R&D is disproportionately greater for larger firms as well as start-ups. In contrast, Guellec and van Pottelsberghe de la Pottierie (2003) conclude a panel study of 17 OECD countries saying "the defence component of government-performed research has a negative impact on business funded R&D, civilian R&D has no impact." Jaumotte and Pain (2005, p.38) find for the performance definition of the data that "An increase of 1 standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%." Khan and Luintel (2006) find negative interaction effects diminishing an overall positive effect (insignificant only for Belgium). Van Elk et al. (2019), using a similar approach to heterogeneity through interaction terms find mixed evidence in OECD panel studies with homogeneity assumption; results become more positive when the authors use interaction effects with public R&D. Falk (2006) shows that universities' R&D triggers additional business R&D in a panel of 21 OECD countries. Becker (2015) supports this result in a survey and explains it extensively. Toole (2007) finds a strong complementarity with a time lag of 3 years for public clinical research with decreasing elasticities adding up to a long-term elasticity of 0.40, and 8 years for public basic research which is u-shaped with long-term elasticity of 1.69. Cincera et al. (2011) mix the analysis of effects of R&D subsidies and publicly performed R&D on private R&D, BERD and R&D personnel, and analyse the causes of differences in its efficiency across OECD countries. Montmartin and Herrera (2015), in a study of 25 OECD countries find that publicly executed R&D has a positive effect, public support a negative effect and tax credit a positive effect. The presence of all the three variables seems to have an impact and leads to a negative impact of subsidies. More public R&D is fruitful in Australia only if it goes to universities rather than other government parts (Bakhtari and Breunig 2018). Deloitte (2017) finds a positive effect of education

[20] An open issue here is the question whether high-tech support is in line with the principle of technological neutrality. To the extent that high-tech firms are credit constrained, the problem should be addressed directly with credit, not with subsidies. Other imperfections must be important as well to justify subsidies.
[21] Interesting results regarding publicly performed R&D affecting growth (instead of business R&D, the main topic of our paper) are the following two. Goel et al. (2008) find a higher rate of return for federal than non-federal R&D, and for defense compared to non-defense R&D. Duverger and van Pottelsberghe de la Potterie (2011) find that business and education R&D enhances growth, but other public R&D (government) does not.

R&D on business funded R&D in many regressions, but the effect of direct government R&D changes sign and statistical significance over the regressions. When education R&D is using the performance version of the data rather than the funding version, the positive correlation also may imply that firms give more money to universities because they outsource some of their own research tasks to them. We can then see the causality as two-way causality through parallel planning and funding of firms, which is closely related to consultancy, knowledge transfer, spillovers, distance, (re-) location and regional policy, as well as education activities of universities (Becker 2015), and all reinforcing the funding of university research by firms' projects. Comin et al. (2018) match the project data of the Fraunhofer Society, a public research organisation, with those of CIS to show positive effects of their interaction. Soete et al. (2019) for the Netherlands and Ziesemer (2019) for Japan find a positive effect of publicly performed R&D on domestic and foreign privately performed R&D, TFP and GDP. Both papers use a vector-error-correction model and analysed where permanent shocks on public investment with all feedback effects.

3. Conclusion: Literature summary of effects of public R&D expenditures and lessons for subsequent research

The literature explaining private R&D, performance or funded, mostly tests R&D subsidies and tax credits as explanatory variables (Becker 2015). The literature using R&D regressors mostly tries to explain productivity, rates of return or patents (Petrin 2018; Soete et al. (2019); Becker 2015; van Elk et al. 2019; Radicic 2014; Khan and Luintel 2006; Guellec and van Pottelsberghe de la Potterie 2004). Therefore, the literature explaining private R&D through publicly performed R&D appears to be small.

Summing up briefly, the overall impression is as follows.

Two meta-studies find little additionality effects from government R&D expenditures whereas a third one by Correa et al. (2013) find clearly positive results. They do not suggest complete crowding out. They average over studies, controlling for heterogeneity and publication bias.[22] The problem often is one of econometric identifiability of effects (Dimos and Pugh 2016).
One approach to dealing with heterogeneity issues of countries is to consider only one country at a time. These studies in Table 2 suggest a positive effect of public on private R&D expenditures; only two papers suggests full crowding out.
The surveys, country-year panel and firm panel analyses as well as the country-specific studies are much less sceptical than the meta-studies and show more positive results with interesting study-specific differentiations. The most frequent result is that there is complementarity between public and private R&D for both tax credits and subsidies. A large group of papers suggests incomplete crowding out.[23]
The papers of section 2.3, which address the effects of R&D performance on business R&D, all find positive effects with the exception of Guellec and van Pottelsberghe De La Potterie (2003) who find a negative effect of defence and a neutral of civilian R&D.

[22] Meta regression analysis itself is controversial: "MRA aims at isolating average effects and by definition it tends to overlook the role of context-specific moderating factors that likely affects the outcomes of specific policy programs." (Grilli et al. 2018, p.3). A detailed study of the methodologies in this area is Cerulli (2010).
[23] Even if additionality is limited, the cumulation of knowledge spillovers adds social value (Antonelli 2019).

We can categorise the firm heterogeneity leading to modifications of the majority of results as characteristics of (i) programs, projects and selection procedures, (ii) subsidy receiving firms, (iii) markets and sector for the R&D outcomes, and (iv) specific periods. Aspects of systems of innovation and transformative change (Schot and Steinmüller 2018) serve as control variables at best implicitly in these four groups of characteristics of heterogeneity and may be useful in the future when trying to clarify the controversial issues and explain heterogeneous results.

Most controversial is the question whether or not large firms respond less to R&D subsidies. Moreover, it is not clear why R&D subsidies are substitutes for tax incentives in some studies, complements or independent in others. Finally, which parts of publicly performed R&D are most stimulating for private R&D is a question that is worth a follow up of the related studies surveyed here.

The literature summary teaches us that important aspects for our empirical analysis are dynamic models with adequate time lags, allowing for mutual interdependence of all variables, including feedback effects from foreign countries, and allowing for country and firm heterogeneity. Major suggestions for future studies are as follows. First, due recognition of lags makes a big difference in the literature. Then, dynamic models should be helpful. Second, besides public R&D stimulating business R&D, there is also the question what the effects on productivity and growth are (Archibugi and Filippetti 2018). That is a separate important literature referred to in the introduction; we exclude it from the survey - together with that on other than innovation related indicators – as they can fill surveys on their own; van Elk et al. (2019) have surveyed it. Third, not only all these effects matter but also their feedback mechanisms to each other do by way of generating multiplier effects. Fourth, long-term ex-post studies, suggested by Petrin (2018), would lead us to methods of time-series analyses. Fifth, research should consider the role of foreign public spillovers (Donselaar and Koopmans 2016). Dealing with these aspects all together implies dealing with input and output additionality (Grilli et al 2018) and answer 'the (not yet resolved) puzzling question: are direct public R&D subsidies really impactful?' (Archibugi and Filippetti 2018). Finally, going beyond finding the consequences of heterogeneity of firm and countries, explaining the heterogeneity of effects of R&D support may be an interesting research topic. Future research, which takes into account these aspects, seems to be promising for all the questions related to R&D support.

References

Abdul Basit, S., Kuhn, T., Ahmed, M. (2018), "The Effect of Government Subsidy on Non-Technological Innovation and Firm Performance in the Service Sector: Evidence from Germany", Business Systems Research, Vol. 9, No. 1, pp. 118-137.

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

Aguiar, Luis, and Philippe Gagnepain (2017) European cooperative R&D and firm performance: Evidence based on funding differences in key actions. International Journal of Industrial Organization 53, 1–31.

Aiello, Francesco and Giuseppe Albanese and Paolo Piselli (2017) Public R&D support in Italy. Evidence from a new firm-level patent data set. MPRA Paper No. 77955, 28 March.

Alecke, B., Mitze, T., Reinkowski, J. and Untiedt, G. (2012), 'Does firm size make a difference? Analysing the effectiveness of R&D subsidies in East Germany'. German Economic Review 13, 174-195.

Almus, Matthias and Dirk Czarnitzki (2003) The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany. Journal of Business & Economic Statistics, Vol. 21, No. 2, pp. 226-23.

Alvarez-Ayuso, Inmaculada C., Chihwa Kao, Desiderio Romero-Jordan (2018). Long run effect of public grants and tax credits on R&D investment: A non-stationary panel data approach. Economic Modelling 75 93–104.

Antonelli, Cristiano (2019). Knowledge exhaustibility public support to business R&D and the additionality constraint. The Journal of Technology Transfer. https://doi.org/10.1007/s10961-019-09727-y.

Antonelli, Cristiano and Francesco Crespi. The "Matthew effect" in R&D public subsidies: The Italian evidence. Technological Forecasting & Social Change 80 (2013) 1523–1534.

Appelt, S. et al. (2016), "R&D Tax Incentives: Evidence on design, incidence and impacts", OECD Science, Technology and Industry Policy Papers, No. 32, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jlr8fldqk7j-en

Archibugi, Daniele, Andrea Filippetti (2018) The retreat of public research and its adverse consequences on innovation. Technological Forecasting & Social Change 127, 97–111.

Aristei, David, Alessandro Sterlacchini & Francesco Venturini (2017) Effectiveness of R&D subsidies during the crisis: firm-level evidence across EU countries, *Economics of Innovation and New Technology*, 26:6, 554-573.

Arqué-Castells, Pere, and Pierre Mohnen (2015) Sunk Costs, Extensive R&D Subsidies and Permanent Inducement Effects. The Journal of Industrial Economics, Volume LXIII, No. 3, 458-494.

Arrow, Kenneth J. (1962) Economic Welfare and the Allocation of Resources for Invention. The Journal of Law and Economics 12, 609-624.

Aysun, Uluc, Zeynep Kabukcuoglu (2017) Interest rates, R&D investment and the distortionary effects of R&D incentives. Mimeo, November.

Azoulay, Pierre, Joshua S. Graff Zivin, Danielle Li, Bhaven N. Sampat (2019) Public R&D Investments and Private-Sector Patenting: Evidence From NIH Funding Rules. Review of Economic Studies (2019) 86, 117–152.

Bakhtiari, Sasan & Robert Breunig (2018) The role of spillovers in research and development expenditure in Australian industries, *Economics of Innovation and New Technology*, 27:1, 14-38.

Barajas, Ascensión and Elena Huergo and Lourdes Moreno (2017) Public Support to Business R&D and the Economic Crisis: Spanish Evidence. CDTI, MPRA, September.

Beck, Mathias, Martin Junge, Ulrich Kaiser (2017) Public Funding and Corporate Innovation. IZA DISCUSSION PAPER No. 11196, DECEMBER.

Becker, Bettina (2015) Public R&D Policies and Private R&D Investment: A Survey of the Empirical Evidence. *Journal of Economic Surveys* Vol. 29, No. 5, pp. 917–942.

Becker, B. and Hall, S.G. (2013) Do R&D strategies in high-tech sectors differ from those in low-tech sectors? An alternative approach to testing the pooling assumption. *Economic Change and Restructuring* 46: 183–202.

Bedu, Nicolas and van der Stocken Alexis (2015) L'impact des subventions régionales à la R&D: le cas des PME aquitaines, Cahiers du GREThA, n°2015-13.

Bérubé, C. and Mohnen, P. (2009) Are Firms That Received R&D Subsidies More Innovative? Canadian Journal of Economics / Revue Canadienne d'Economique, Vol. 42, No. 1, 206-225.

Blasio, G., D. Fantino, and G. Pellegrini. 2014. "Evaluating the Impact of Innovation Incentives: Evidence from an Unexpected Shortage of Funds." Industrial and Corporate Change 23 (5): 1–30. doi:10.1093/icc/dtu027.

Bloch, C. and Graversen, E.K. (2012) Additionality of public R&D funding for business R&D—A dynamic panel data analysis. *World Review of Science, Technology and Sustainable Development* 9: 204–220.

Bloom, Nicholas, John Van Reenen, Heidi Williams (2019). A Toolkit of Policies to Promote Innovation CEP Discussion Paper No 1634, July.

Bohnstedt, Anna (2014) Are Public and Private R&D Investments Complements or Substitutes?, Ruhr Economic Papers, No. 485, ISBN 978-3-86788-551-5, http://dx.doi.org/10.4419/86788555.

Bronzini, Raffaello and Eleonora Iachini. Are Incentives for R&D Effective? Evidence from a Regression Discontinuity Approach American Economic Journal: Economic Policy 2014, 6(4): 100-134. http://dx. doi. org/1 0.125 7 /pol. 6. 4. 1 00.

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

Buchmann, Tobias & Micha Kaiser (2019) The effects of R&D subsidies and network embeddedness on R&D output: evidence from the German biotech industry, Industry and Innovation, 26:3, 269-294, DOI: 10.1080/13662716.2018.1438247.

Buigues, Pierre-André, and Khalid Sekkat (2011) Public Subsidies to Business: An International Comparison. Journal of Industry, Competition, and Trade, 11, 1–24.

Busom, Isabel (2000) An Empirical Evaluation of The Effects of R&D Subsidies, Economics of Innovation and New Technology, 9:2, 111-148.

Busom, Isabel, Beatriz Corchuelo, Ester Martínez-Ros (2014) Tax incentives… or subsidies for business R&D? Small Business Economics 43:571–596.

Čadil, Jan, Karel Mirošník Ján Rehák (2017) The lack of short-term impact of cohesion policy on the competitiveness of SMEs. International Small Business Journal: Researching Entrepreneurship, Vol. 35(8), 991–1009.

Carboni, O.A. (2011) R&D subsidies and private R&D expenditures: Evidence from Italian manufacturing data. *International Review of Applied Economics* 25: 419–439.

Catozzella, A. and Vivarelli, M. (2011), "Beyond Additionality: Are Innovation Subsidies Counterproductive?" IZA Discussion Paper, No. 5746.

Cerulli, R., 2010. Modelling and measuring the effect of public subsidies on business R&D: a critical review of the econometric literature. Economic Record 86, 421–449.

Cerulli, Giovanni & Bianca Potì (2012) The differential impact of privately and publicly funded R&D on R&D investment and innovation: the Italian case, Prometheus, 30:1,113-149.

Cincera, Michele, Dirk Czarnitzki et Susanne Thorwarth (2011) Efficiency of public spending in support of R&D activities. Reflets et Perspectives, L, 2011/1-2, 131-139.

Clausen, T.H., 2009. Do subsidies have positive impacts on R&D and innovation activities at the firm level? Structural Change and Economic Dynamics 20(4),239–253.

Coccia, Mario (2009) What is the optimal rate of R&D investment to maximize productivity growth? Technological Forecasting & Social Change 76, 433–446.

Coccia, Mario (2010) Public and Private Investment in R&D: Complementary Effects and Interaction with Productivity Growth », paru dans ERIEP, Number 1, Selected Papers, Innovation and New Industries, Public and Private Investment in R&D: Complementary Effects and Interaction with Productivity Growth, mis en ligne le 22 juillet, URL : http://revel.unice.fr/eriep/index.html?id=3085.

Cohen, Wesley M., Richard R. Nelson, John P. Walsh (2002) Links and Impacts: The Influence of Public Research on Industrial R&D. MANAGEMENT SCIENCE, Vol. 48, No. 1, January pp. 1-23.

Colombo, Massimo G., Luca Grilli, Samuele Murtinu (2011) R&D subsidies and the performance of high-tech start-ups. Economics Letters 112, 97–99.

Comin, Diego, Georg Licht, Maikel Pellens, and Torben Schubert (2018). Do Companies Benefit from Public Research Organizations? The Impact of the Fraunhofer Society in Germany. Mimeo, June 4.

Corchuelo, M. Beatriz and Ester Martínez-Ros (2010) Who Benefits from R&D Tax Policy? Cuadernos de Economía y Dirección de la Empresa. Núm. 45, diciembre, págs. 145-170.

Correa, Paulo, Luis Andrés, Christian Borja-Vega (2013) The Impact of Government Support on Firm R&D Investments A Meta-Analysis. World Bank Policy Research Working Paper 6532.

Corredoira, Rafael A., Brent Goldfarb & Yuan Shi (2017) Federal Funding and the Rate and Direction of Inventive Activity. Draft version: 2.6, April. SSRNid-2974308.

CPB (2014) A Study on R&D Tax Incentives Final report. TAXATION WORKING PAPER N. 52.

Czarnitzki, Dirk; Delanote, Julie (2015): R&D policies for young SMEs: Input and output effects, ZEW Discussion Papers, No. 15-032.

Czarnitzki, Dirk and Julie Delanote (2017). Incorporating innovation subsidies in the CDM framework: empirical evidence from Belgium. Economics of Innovation and New Technology, VOL. 26, NOS. 1–2, 78–92. http://dx.doi.org/10.1080/10438599.2016.1202514.

Czarnitzki, D., Ebersberger, B. and Fier, A. (2007) The relationship between R&D collaboration, subsidies and R&D performance: Empirical evidence from Finland and Germany. *Journal of Applied Econometrics* 22: 1347–1366.

Czarnitzki, Dirk and Andreas Fier (2002) Do Innovation Subsidies Crowd Out Private Investment? Evidence from the German Service Sector. *Applied Economics Quaterly (Konjunkturpolitik)* 48(1), 1-25.

Czarnitzki, Dirk, Elena Huergo, Mila Köhler, Pierre Mohnen, Sebastian Pacher, Tuomas Takalo, Otto Toivanen (2014) Structural estimation of targeted R&D subsidies: International evidence. July 31st.

Czarnitzki, D. and Hussinger, K. (2004) The link between R&D subsidies, R&D spending and technological performance. ZEW Discussion Paper 04–56.

Czarnitzki, Dirk & Katrin Hussinger (2018) Input and output additionality of R&D subsidies, Applied Economics, 50:12, 1324-1341.

Czarnitzki, D. and Licht, G. (2006) Additionality of public R&D grants in a transition economy. *Economics of Transition* 14: 101–131.

Czarnitzki, D. and Lopes-Bento, C. (2012) Evaluation of public R&D policies: A cross-country comparison. World Review of Science, Technology and Sustainable Development 9: 254–282.

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

Czarnitzki, Dirk, and Andrew A. Toole (2007) Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty. Review of Industrial Organization 31: 169–181. DOI 10.1007/s11151-007-9152-x.

Dai, Xiaoyong and Liwei Cheng (2015) The effect of public subsidies on corporate R&D investment: An application of the generalized propensity score. Technological Forecasting & Social Change 90 410–419.

David, Paul A., Bronwyn H. Hall and Andrew A. Toole (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, *Research Policy* 29: 497–529.

Deloitte (2017) Research, innovation and economic growth: Knowledge production function and R&D investment. Brussels.

Diamond, Arthur M. Jr (1999) Does Federal Funding “Crowd In” Private Funding Of Science? Contemporary Economic Policy, Vol. 17, No. 4, 423-431.

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

Donselaar, Piet, and Carl Koopmans (2016) The fruits of R&D: Meta-analyses of the effects of Research and Development on productivity. Research Memorandum 2016-1.

Duguet, E. (2004) Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data. *Revue D'Economie Politique* 114: 263–292.

Dumont, Michel (2017) Assessing the policy mix of public support to business R&D. Research Policy, Volume 46, Issue 10, 1851-1862.

Duverger, Catherine; van Pottelsberghe de la Potterie, Bruno (2011): Determinants of productivity growth: Science and technology policies and the contribution of R&D, EIB Papers, ISSN 0257-7755, European Investment Bank (EIB), Luxembourg, Vol. 16, Iss. 1, pp. 53-60.

Dvouletý, O.; Longo, C. M.; Blažková, I.; Lukeš, M. & Andera, M. (2018). Are Publicly Funded Czech Incubators Effective? The Comparison of Performance of Supported and Non-Supported Firms. *European Journal of Innovation Management,* Vol. 21, No. 4, pp. 543-563.

Economics Insight (2015). What is the relationship between public and private investment in science, research and innovation. London: Economic Insight.

Elias Einiö (2014) R&D Subsidies And Company Performance: Evidence from Geographic Variation in Government Funding Based on the ERDF Population-Density Rule. The Review of Economics and Statistics, October 2014, 96(4): 710–728.

Elk, Roel van, Bas ter Weel, Karen van der Wiel, Bram Wouterse (2019). A macroeconomic analysis of the returns to public R&D investments. De Economist 167:45–87.

Falk, Martin (2006) What drives business Research and Development (R&D) intensity across Organisation for Economic Co-operation and Development (OECD) countries? Applied Economics, 38:5, 533-547, DOI: 10.1080/00036840500391187.

Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt.

Finger, S.R. (2008), 'An Empirical Analysis of R&D Competition in the Chemicals Industry'. Available from: http://ssrn.com/abstract=1323919.

Fornahl, Dirk, Tom Broekel, Ron Boschma (2011) What drives patent performance of German biotech firms? The impact of R&D subsidies, knowledge networks and their location. Papers in Regional Science, Volume 90 Number 2, June.

García-Quevedo, José (2004) Do Public Subsidies Complement Business R&D? A Meta-Analysis of the Econometric Evidence. KYKLOS, Vol. 57 – 2004 – Fasc. 1, 87–102.

Gaster, Robin (2017) Impacts of the SBIR/STTR Programs: Summary and Analysis. Incumetrics mimeo, May.

Gelabert, Liliana, Andrea Fosfuriz, Josep A.Tribo (2009) Does the effect of public support for R&D depend on the degree of appropriability? The Journal of Industrial Economics LVII, No. 4,736-767.

Giga, Aleksandar, Andrea Belz, Richard Terrile, Fernando Zapatero, Dalia Yadegar (2016) Helping the Little Guy: The Impact of Government Grants on Small Technology Firms. Mimeo, SSRNid3054809.

Goel, Rajeev K., James E. Payne, Rati Ram (2008). R&D expenditures and U.S. economic growth: A disaggregated approach. Journal of Policy Modeling 30 237–250.

González, X. and Pazó, C. (2008) Do public subsidies stimulate private R&D spending? *Research Policy* 37: 371–389.

González, X., Jaumandreu, J. and Pazó, C. (2005) Barriers to innovation and subsidy effectiveness. *RAND Journal of Economics* 36: 930–950.

Goolsbee, A (1998) Does government R&D policy mainly benefit scientists and engineers? NBER WP 6532.

Görg, H. and Strobl, E. (2007) The effect of R&D subsidies on private R&D. *Economica* 74: 215–234.

Grabińska, Barbara and Katarzyna Stabryła-Chudzio (2017) Increasing importance of EU spending on business research and innovation - evidence from Poland. TAKE 2017 – Theory and Applications in the Knowledge Economy, conference volume.

Graves, Samuel B. and Nan S. Langowitz (1996) R&D Productivity: A Global Multi-Industry Comparison. Technological Forecasting and Social Change 53, 125-137.

Grilli, Luca, Mariana Mazzucato, Michele Meoli, Giuseppe Scellato (2018) Sowing the seeds of the future: Policies for financing tomorrow's innovations. Technological Forecasting & Social Change 127, 1–7.

Guceri, Irem (2018) Will the real R&D employees please stand up? Effects of tax breaks on firm-level outcomes. International Tax Public Finance 25:1–63. https://doi.org/10.1007/s10797-017-9438-3.

Guellec, D. and Van Pottelsberghe de la Potterie, B. (2003) The impact of public R&D expenditure on business R&D. *Economics of Innovation and New Technology* 12: 225–243.

Guellec, Dominique and Bruno Van Pottelsberghe de la Potterie (2004) From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter? Oxford Bulletin of Economics and Statistics, 66, 3, 353-378.

Hall, B. H. (2002). The financing of research and development. Oxford Review of Economic Policy 18(1), 35-51.

Hall, Bronwyn H., (2019) Tax Policy for Innovation. NIESR Discussion Paper No. 506, June.

Hall, Bronwyn H., Francesca Lotti and Jacques Mairesse (2009) Innovation and productivity in SMEs: empirical evidence for Italy. Small Business Economics 33:13–33

Hall, Bronwyn and John Van Reenen (2000) How effective are fiscal incentives for R&D? A review of the Evidence. Research Policy 29, 449–469.

Haskel J., G. Wallis, 2013, Public support for innovation, intangible investment and productivity growth in the UK market sector, *Economics Letters*, 119, 195–198.

Haskel, J., Hughes, A., Bascavusoglu-Moreau, E. (2014). The economic significance of the UK science base. A Report for the Campaign for Science and Engineering. UK Innovation Research Centre, London.

Herrera, Liliana, Edna R. Bravo Ibarra (2010) Distribution and effect of R&D subsidies: A comparative analysis according to firm size. Intangible Capital, 6(2): 272-299. doi:10.3926/ic.2010.v6n2.

Hottenrott, Hanna, Elmar Lins & Eva Lutz (2017b): Public subsidies and new ventures' use of bank loans, Economics of Innovation and New Technology 27(8), 808-830, DOI:10.1080/10438599.2017.1408200.

Hottenrott, Hanna, Cindy Lopes-Bento (2014). (International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes. Research Policy 43 1055–1066.

Hottenrott, Hanna, Cindy Lopes-Bento, Reinhilde Veugelers (2017a) Direct and Cross-Scheme Effects in a Research and Development Subsidy Program. Research Policy, Volume 46, Issue 6, 2017, pp. 1118-1132.

Howell, S. T. (2017). Financing innovation: evidence from R&D grants. The American Economic Review, 107(4), 1136-1164.

Hünermund, Paul; Czarnitzki, Dirk (2015) Estimating the Local Average Treatment Effect of R&D Subsidies in a Virtual Common Pot, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2015: Ökonomische Entwicklung - Theorie und Politik - Session: Innovation 1, No. D21-V2, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft.

Hud, Martin, Katrin Hussinger (2015) The impact of R&D subsidies during the crisis. Research Policy 44 1844–1855.

Hünermund, Paul and Dirk Czarnitzki (2019) Estimating the Local Average Treatment Effect of R&D Subsidies in a Pan-European Program. Research Policy, Volume 48, Issue 1, 115-124.

Huergo, Elena and Lourdes Moreno (2017) Subsidies or loans? Evaluating the impact of R & D support programmes. Research Policy 46, 1198–1214.

Hujer, Reinhard and Dubravko, Radic (2005). EVALUATING THE IMPACTS OF SUBSIDIES ON INNOVATION ACTIVITIES IN GERMANY. Scottish Journal of Political Economy, Vol. 52, No. 4, September.

Hussinger, K. (2008) R&D and subsidies at the firm level: An application of parametric and semiparametric two-step selection models. *Journal of Applied Econometrics* 23: 729–747.

Ilbeigi, Alireza (2017) Public R&D Policy Impact Evaluation (Propensity Score Matching and Structural Modeling Estimations). PhD thesis, U Trento.

Jaumotte, F. and Pain, N. (2005) ‘Innovation in the Business Sector’, OECD Economics Department Working Paper No. 459, OECD, Paris.

Henningsen, M., Haegeland, T. and Møen, J. (2015) Estimating the additionality of R&D subsidies using proposal evaluation data to control for firms’ R&D intentions. Journal of Technology Transfer 40: 227–251.

Hyytinen, A. and Toivanen, O. (2005) Do financial constraints hold back innovation and growth? Evidence on the role of public policy. *Research Policy* 34: 1385–1403.

Jaffe, Adam B. and Trinh Le (2015) The Impact of R&D Subsidy on Innovation: a Study of New Zealand Firms. NBER Working Paper No. 21479, August.

Kaiser, Ulrich (2006). Private R&D and Public R&D subsidies: Microeconometric Evidence for Denmark. Nationaløkonomisk Tidsskrift 144: 1-17.

Kasahara, Hiroyuki, Katsumi Shimotsu, Michio Suzuki (2014) Does an R&D tax credit affect R&D expenditure? The Japanese R&D tax credit reform in 2003. Journal of the Japanese and the International Economies 31, 72–97.

Khan, Mosahid and Kul B. Luintel (2006) Sources of Knowledge and Productivity: How Robust Is The Relationship? STI/WORKING PAPER 6.

Klette, Tor Jakob, and Jarle Møen, Zvi Griliches Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies, Research Policy 29, 2000. 471–495.

Klette, T.J. and Møen, J. (2012) R&D investment responses to R&D subsidies: A theoretical analysis and a microeconometric study. *World Review of Science, Technology and Sustainable Development* 9: 169–203.

Koehler, Mila (2018) Estimating the Benefits of R&D Subsidies for Germany. Discussion Paper No. 18-002.

Koehler, Mila and Bettina Peters (2017) Subsidized and Non-subsidized R&D Projects: Do They Differ? Discussion Paper No. 17-042.

Koga, Tadahisa (2005) R&D Subsidy and Self-Financed R&D: The Case of Japanese High-Technology Start-Ups. Small Business Economics 24: 53–62.

Lach, S. (2002) Do R&D subsidies stimulate or displace private R&D? Evidence from Israel. *Journal of Industrial Economics* 50: 369–390.

Lanahan, Lauren (2016) Multilevel public funding for small business innovation: a review of US state SBIR match programs. Journal of Technology Transfer 41: 220–249.

Lanahan, L., Graddy-Reed, A., & Feldman, M. P. (2016). The domino effects of federal research funding. PloS one, 11(6), e0157325.

Lee, Chang-Yang (2011) The differential effects of public R&D support on firm R&D: Theory and evidence from multi-country data. Technovation 31, 256–269.

Lööf, Hans and Almas Heshmati (2005) The Impact of Public Funding on Private R&D investment. New Evidence from a Firm Level Innovation Study (Additionality or Crowding Out? On the effectiveness of R&D subsidies) CESIS WP No. 06.

Luintel , Kul B., Mosahid Khan, Konstantinos Theodoridis (2014) On the robustness of R&D. Journal of Productivity Analysis 42:137–155.

Mariani, Marco, Fabrizia Mealli (2017) The Effects of R&D Subsidies to Small and Medium-Sized Enterprises. Evidence from a Regional Program. Italian Economic Journal. DOI 10.1007/s40797-017-0062-2.

Marino, Marianna, Stephane Lhuillery, Pierpaolo Parrotta, Davide Salaf (2016) Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. Research Policy 45, 1715–1730.

Mazzucato, Mariana (2018) Mission-Oriented Innovation Policy: Challenges and Opportunities. In: European Commission (2018) Science, Research and Innovation Performance of the EU 2018. Strengthening the foundations for Europe's future. Brussels. Pages 396-427.

Meuleman, Miguel, Wouter De Maeseneire (2012) Do R&D subsidies affect SMEs' access to external financing? Research Policy 41 580–591.

Møen, Jarle, and Helge Sandvig Thorsen (2017) Publication Bias in the Returns to R&D Literature. Journal of the Knowledge Economy 8:987–1013.

Mohnen, Pierre (2018). The role of research and development in fostering economic performance. A survey of the macro-level literature and policy implications for Finland, Final report, February.

Mohnen, P. and B. Lokshin (2010) What does it take for an R&D tax incentive policy to be effective. In: Reforming Rules and Regulations: Laws, Institutions, and Implementation edited by Vivek Ghosal. CES IFO Seminar Series. 33-58. Cambridge: MIT Press.

Montmartin, Benjamin, and Marcos Herrera (2015) Internal and external effects of R&D subsidies and fiscal incentives: Empirical evidence using spatial dynamic panel models. Research Policy 44, 1065–1079.

Montmartin, Benjamin, Marcos Herrera, Nadine Massard (2018). The impact of the French policy mix on business R&D: How geography matters. Research Policy 47 2010–2027.

Mulligan, Kevin, Helena Lenihan, and Justin Doran (2017) Dynamic complementarities in the policy mix for innovation: A firm-level impact evaluation of science and innovation policy using panel data. Working paper, January.

Nakamura, A. and M. Nakamura (1998). Model specification and endogeneity. Journal of Econometrics, 83, pp.213-237.

Negassi, Syoum and Jean-Francois Sattin (2014). Evaluation of Public R&D Policy: A Meta-Regression Analysis. WORKING PAPER NO. 2014-09.

Neicu, Daniel (2016a) Learning how to behave. An analysis of the behavioural changes induced by public support for R&D. PhD thesis, Faculty of Economics and Business, KU Leuven – University of Leuven.

Neicu, Daniel (2016b) Mix and match: evaluating the additionality of an R&D policy mix. November.

Neicu, Daniel, Peter Teirlinck and Stijn Kelchtermans (2016) Dipping in the policy mix: Do R&D subsidies foster behavioral additionality effects of R&D tax credits? Economics of Innovation and New Technology, VOL. 25, NO. 3, 218–239.

Nelson, Richard R. (1959) The Simple Economics of Basic Scientific Research. Journal of Political Economy, Vol. 67, No. 3 (June), pp. 297-306.

Ngo, P., Stanfield, J. (2017). Does Government Spending Crowd Out R&D Investment? Evidence from Government-Dependent Firms and Their Peers. FIRN Research Paper No. 2581273.

Özcelik, E. and Taymaz, E. (2008) R&D support programs in developing countries: The Turkish experience. *Research Policy* 37: 258–275.

Parisi, Maria Laura, Alessandro Sembenelli (2003). Is Private R&D Spending Sensitive to Its Price? Empirical Evidence on Panel Data for Italy. Empirica 30: 357–377, 2003.

Plank, Josef, and Claudia Doblinger (2018) The firm-level innovation impact of public R&D funding: Evidence from the German renewable energy sector. Energy Policy 113, 430–438.

Pöschel, Carla (2019) Incentive Effects of R&D Tax Incentives – A Meta-Regression Analysis focusing on R&D Policy Designs. arqus Discussion Paper No. 243, August.

Radas, Sonja, Ivan-Damir Anića, AzraTafro, Vanja Wagner (2015) The effects of public support schemes on small and medium enterprises. Technovation 38, 15–30.

Radicic, Dragana (2014) The Effectiveness of R&D and Innovation Policy in Promoting Innovation in European SMEs: an Empirical Investigation of Additionality Effects. PhD thesis.

Radicic, Dragana and Geoffrey Pugh (2017) R&D Programmes, Policy Mix, and the 'European Paradox': Evidence from European SMEs. Science and Public Policy, 44(4), 497–512.

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

Petrin, Tea (2018) A literature review on the impact and effectiveness of government support for R&D and innovation. Working Paper, February.

Reinkowski, Janina; Alecke, Björn; Mitze, Timo; Untiedt, Gerhard (2010). Effectiveness of Public R&D Subsidies in East Germany – Is it a Matter of Firm Size?, Ruhr Economic Papers, No. 204, ISBN 978-3-86788-233-0, Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), Essen.

Romero-Jordán, Desiderio, María Jesús Delgado-Rodríguez, Inmaculada Álvarez-Ayuso, Sonia de Lucas-Santos (2014) Assessment of the public tools used to promote R&D investment in Spanish SMEs. Small Business Economics 43:959–976.

Salter, Ammon J. and Ben R. Martin (2001). The economic benefits of publicly funded basic research: a critical review. Research Policy 30, 509–532.

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

Serrano-Velarde, Nicolas (2008) Crowding-Out At The Top: The Heterogeneous Impact of R&D Subsidies on Firm Investment. European University Institute, November 24. Mimeo.

Shell, Karl (1967) A Model of Inventive Activity and Capital Accumulation. In Essays on the Theory of Optimal Economic Growth, edited by Karl Shell, 67-85. Cambridge, MA: The MIT Press.

Soete, Luc, Bart Verspagen and Thomas Ziesemer (2019) The productivity effect of public R&D in the Netherlands, UNU-MERIT WP 2017-021. Economics of Innovation and New Technology. Online.

Spengel, Christoph, Christian Rammer, Katharina Nicolay, Olena Pfeiffer, Ann-Catherin Werner, Marcel Olbert, Florence Blandinières, Martin Hud, Bettina Peters (2017) : Steuerliche FuE-Förderung: Studie im Auftrag der Expertenkommission Forschung und Innovation, Studien zum deutschen Innovationssystem, No. 15-2017.

Takalo, Tuomas, Tanja Tanayama (2010) Adverse selection and financing of innovation: is there a need for R&D subsidies? Journal of Technology Transfer 35: 16–41.

Takalo, Tuomas, Tanja Tanayama, Otto Toivanen (2013a). Market failures and the additionality effects of public support to private R&D: Theory and empirical implications. International Journal of Industrial Organization 31 634–642.

Takalo, Tuomas, Tanja Tanayama, and Otto Toivanen (2013b) Estimating the Benefits of Targeted R&D Subsidies. The Review of Economics and Statistics, 95(1): 255–272.

Thomson, Russell (2017) The Effectiveness of R&D Tax Credits. The Review of Economics and Statistics, July 99(3): 544–549.

Toole, Andrew A. (2007) Does Public Scientific Research Complement Private Investment in Research and Development in the Pharmaceutical Industry? Journal of Law and Economics, vol. 50 (1), 81-104.

Ugur, Mehmet, Eshref Trushin (2018) Asymmetric information and heterogeneous effects of R&D subsidies: Evidence on R&D investment and employment of R&D personel. GPERC WP 68.

Vanino, Enrico, Stephen Roper, Bettina Becker (2019) Knowledge to money: Assessing the business performance effects of publicly-funded R&D grants. Research Policy 48 1714–1737.

Wallsten, Scott J. (2000) The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program. The RAND Journal of Economics, Vol. 31, No. 1, pp. 82-100.

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

Widmann, Rainer (2017) The effect of government research grants on firm innovation: theory and evidence from Austria. October.

Wolff, G., Reinthaler, V., 2008. The effectiveness of subsidies revisited: accounting for wage and employment effects in business R&D. Research Policy 37, 1403–1412.

Ziesemer, T. (1991) Human Capital, Market Structure and Taxation in a Growth Model with Endogenous Technical Progress, Journal of Macroeconomics, Vol.13, 1991, No.1, Winter, 47-68.

Ziesemer, T. (1995) Endogenous Growth with Public Factors and Heterogeneous Human Capital Producers, Finanzarchiv, Neue Folge, Vol. 52, Issue 1, 1-20.

Ziesemer, T. (2019) Japan's productivity and GDP growth: The role of GBAORD, public and foreign R&D. UNU-MERIT WP 2019-029.

Zúñiga-Vicente, Ángel, and José, César Alonso-Borrego, Francisco J. Forcadell, José I. Galán (2014) Assessing the effect of public subsidies on firm R&D investment: a survey. Journal of Economic Surveys Vol. 28, No. 1, pp. 36–67.

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