Towards a portfolio of additionality indicators

Dirk Czarnitzki and Koenraad Debackere

dirk.czarnitzki@kuleuven.be
koenraad.debackere@kuleuven.be

ECOOM KU Leuven
Faculty of Economics and Business
Naamsestraat 61 – P.O. 3551
B-3000 Leuven

Context

R&D subsidies came about because of market imperfections. R&D entails the non-excludability of a public good, as Arrow (1962) stated: "No amount of legal protection can make a thoroughly appropriable commodity of something as intangible as information. The very use of the information in any productive way is bound to reveal it, at least in part. Mobility of personnel among firms provides a way of spreading information. Legally imposed property rights can provide only a partial barrier, since there are obviously enormous difficulties in defining in any sharp way an item of information and differentiating it from similar sounding items." Private investments in R&D can never be fully appropriated because other companies have the opportunity to free ride. This leads to underinvestment in R&D activities: the level of R&D expenditure will be below the socially desirable optimum.

The economic justification for governmental intervention for private sector R&D activities relies on the familiar market failure arguments (Arrow, 1962). Given these market failure arguments, most governments in industrialized economies attempt to correct them by designing policies, like for instance intellectual property right systems to improve appropriability of knowledge, tax reliefs to reduce the cost of R&D (see Hall and Van Reenen, 2000), direct subsidy programs (see e.g. David et al., 2000, for a survey), public venture capital (see Hall and Lerner, 2010, for a survey) or loans with low interest rates. A detailed overview of the existing policy mix and its potential effects on R&D activities would however be beyond the scope of this study, since we are merely interested in direct subsidies.

According to Arrow (1962), the market failure arguments can be summarized into three main issues: (i) increasing returns, (ii) inappropriability of knowledge and (iii) uncertainty.

(i) Information is characterized by increasing returns to scale insofar that once the information is produced, it can be used multiple times, regardless of the scale of production. Since the same unit of information can be used multiple times by the same or by a different user, the cost of information production is not dependent on the scale on which the information is used (Arrow, 1962, 1996, 1999; Lamberton, 1996). There are generally relative high fixed costs of establishing an economic unit for the production of information and the marginal cost of providing a unit of information is far less than the average costs of information production. Indeed, from a welfare point of view, the information concerning an invention should be available completely free of charge, with the exception of the cost of transmitting the information (often very low or close to zero though). Even though this would ensure an optimal utilization of the information, it would present very little, if not no, incentive to invest in knowledge production.

(ii) In terms of inappropriability, it is a well-known fact that because of the non-rival and non-exclusive character of knowledge, a firm can never appropriate all the benefits of its R&D investments, even though it has to bear the entire costs. A part of the created knowledge always spills over to other agents, so that many agents can benefit from an investment done by the one firm. Hence, the incentive to be the investing agent is reduced due to this inappropriability of knowledge.

(iii) The third argument is linked to the uncertainty that is concurrent to innovative activities. As a matter of fact, innovation is not only uncertain in that one does not always know whether the desired result of the technological change or the innovation will be obtained in terms of output, but very often, one cannot be sure about the market success of an innovation either. Indeed, the path from a brilliant idea to a technical invention and eventually to a successful market application is long, risky and sinuous. In other words, the output of an invention or an innovation can never be perfectly predicted by its input (Arrow, 1962). Hence, in order to undertake such an uncertain project, a firm has to be willing to bear the inherent risk of this endeavour. Since the assumption is that firms are often risk-averse, this will lead to a sub-optimal allocation of risk, meaning that there will be discrimination against risky projects (Arrow and Lind, 1970). In line with the uncertainty (moral hazard) argument, firms often face financial constraints if they do not have sufficient internal resources to undertake an R&D project. Indeed, R&D investments are generally characterized by high firm specific investment and adjustment costs on the one hand, and low collateral value on the other hand. An important share of R&D investment consists in financing R&D employees and training, and hence, a large part of the investment is immediately sunk. Compared to investment in physical capital, R&D itself cannot be used as collateral in credit negotiations (see Hall (2002) for a comprehensive survey of financial constraints). Hence, R&D investments are often hampered by a lack of external lenders or investors. Finally, the market uncertainty for new products delays investment in R&D, reducing the total R&D in the economy. This is even more accurate for projects of more basic research, as the latter are further away from the market and its potential use may be largely unknown by the time of the investment (see e.g. Czarnitzki and Hottenrott, 2011, Czarnitzki et al., 2011). Recent literature (real options theory; see e.g. Pindyck and Dixit, 1994) emphasizes the irreversibility of investments. In other words, firms incur additional opportunity costs by turning down the option to wait for information, and thus by investing today, they eliminate their chance of investing at any time in the future. As a consequence of this uncertainty, investment will decrease. See Czarnitzki and Toole (2007, 2011) for empirical applications on R&D investment. They indeed find that investments fall as product market uncertainty increases.

While the third argument relates to uncertainty and financial market constraints, the two prior arguments, namely the inappropriability of R&D and the increasing returns are associated with positive spillovers and increased consumer surplus. In practice this means that it is socially desirable to subsidize an R&D project if it is associated to high social returns (and provided that the project in question would not have taken place if the firm would have been left on its own, as the project cost may not cover the expected private return). As a consequence of the above, it is a largely shared view that R&D activities are difficult to finance in a freely competitive market place. Support of this view in the form of economic-theory modelling dates back to Schumpeter (1942) and was further developed by Nelson (1959) and Arrow (1962).

Given these insights, R&D subsidies have become a standard policy instrument. The big challenge for governments then obviously is to allocate public funding only to those projects that are socially beneficial and would not be carried out in the absence of a subsidy. This is however not straightforward as companies always have an incentive to apply for public funding. It could be the case that a subsidy merely replaces – or crowds out – private money and does not generate additional R&D investments.

The key question thus becomes: "How much would a firm that has received a subsidy, have spent on R&D if it would not have been subsidized?" This key question has given rise to a myriad of research studies on additionality (or the absence thereof) of public and private funding in R&D. In this contribution, we want to review and highlight the various approaches towards measuring and mapping additionality to conclude that there is a need for a portfolio approach to quantify and qualify the existence of additionality effects in R&D.

Measuring and mapping additionality: a review of the state-of-the-art

During the last decade, micro-econometric c*ounterfactual impact evaluations* have become an important tool in the area of enterprise support policies. It became standard to use econometric methods, such as:

- Matching estimators
- (Conditional) Difference-in-Difference regressions
- Instrumental variable regressions
- More recently: Regression Discontinuity Designs

While, for quite some policy and practical reasons, it is not standard (yet) to use methods, such as:

- Randomized control trials
- Natural experiments

This plethora of sophisticated methodological approaches is important since:

- The firms select themselves into the programs
- Whereby governments pick winners
- With as a result that:
    - Treated firms cannot be compared with non-treated firms without further adjustment for deriving effects of policies
    - Treatment is an endogenous variable in (OLS) regression models, and results will be biased if this endogeneity is not addressed properly

Therefore all econometric evaluation methods seek to establish a *correct* control group approach to derive e.g. the treatment effect on the treated, i.e.

- How many jobs would a treated firm have created if it had not been treated?
- How much would have a firm invested in innovation activities if it had not been subsidized?
- Which sales with new products would a firm have achieved if it had not gotten a start-up grant?

When linking treatment to the various forms of government interventions on R&D, various additionality effects need further attention. In a recent Policy Brief by DG Competition (May 2016), it was thus stated that the aid's incentive effect will typically be assessed by looking at the three main dimensions of additionality: input additionality, output additionality and behavioural additionality.

Input additionality

The measurement and mapping of input additionality has been the main focus of a plethora of empirical examinations. The theoretical justification for governmental intervention in the market for R&D due to positive external effects provides a starting point for this modeling approach. For an evaluation of the impact of public R&D subsidies, the classical evaluation problem involving the estimation of a counterfactual situation is taken into account. The econometric literature available to solve problems of missing observations on counterfactual situations is by now well established. Relying on data obtained through the CIS surveys on the one hand and the R&D surveys on the other hand, a myriad of evaluative studies measuring input additionality have been executed.

Using this approach, it is shown that subsidies yield a positive treatment effect with respect to private R&D spending in the Flemish samples studied (Aerts and Czarnitzki, 2006). The outcome variables considered in the analysis were the R&D expenditure at the firm level in 2000, *RD*. However, as the distribution of this indicator is very skewed in the economy, we also investigate the R&D intensity, *RDINT* (R&D expenditure / turnover*100), and the logs of *RD* and *RDINT.* For example, the R&D intensity (*RDINT*) of subsidized firms is about 4.4% on average. In the selected control group, however, it amounts only to 2.2%. Thus, the treatment effect due to subsidies is about 2.2 percentage points in R&D intensity. Similar results are found in R&D in levels (*RD*). The funding also yields an increase in R&D of about 50% roughly.

Overview main results by Aerts and Czarnitzki (2006):

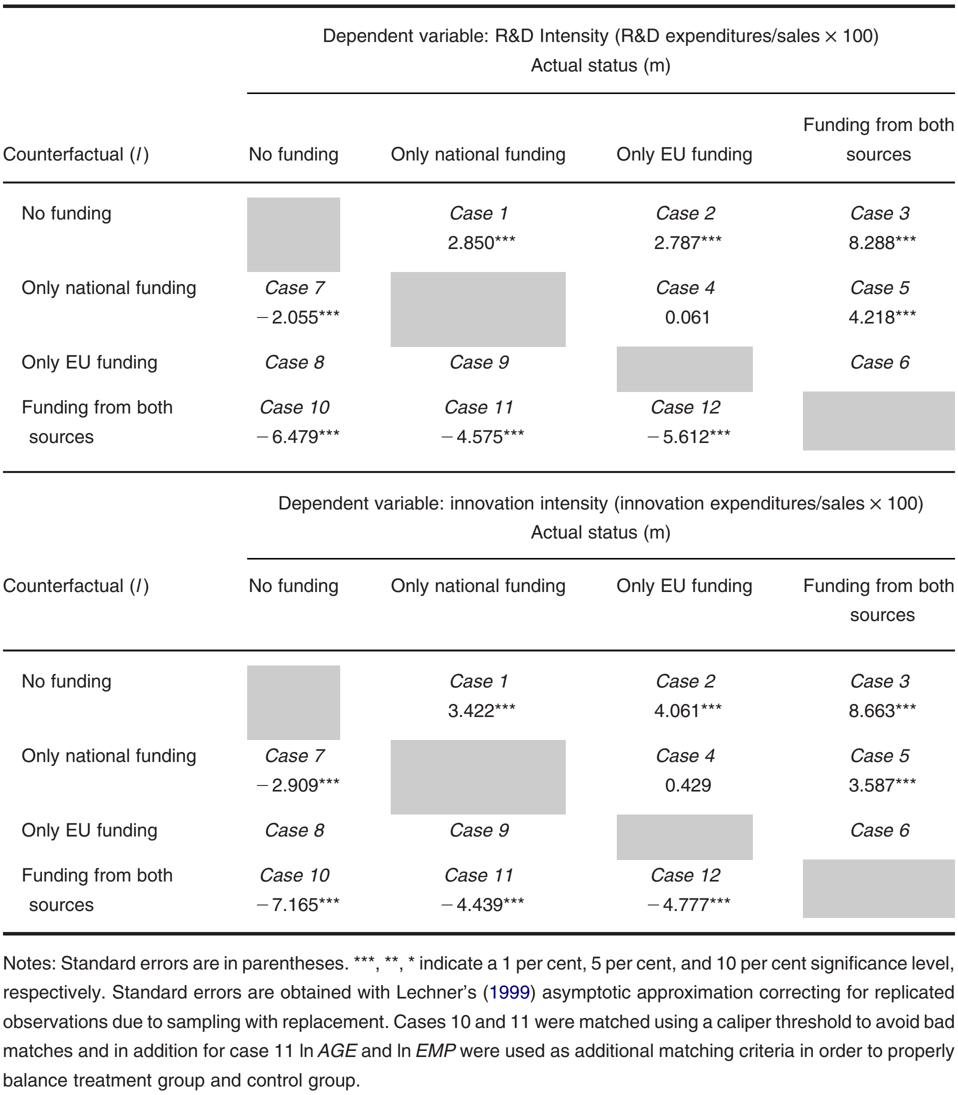
	Subsidized firms $N_1 = 174$		Selected control group $N_0 = 174$		p-value of two-sided t-test on mean differences[b)]
Variable	Mean	Std. Dev.	Mean	Std. Dev.	
ln(*EMP*)	4.379	1.408	4.369	1.302	p = 0.952
SME dummy	0.557	0.498	0.621	0.487	p = 0.320
NPRJ	0.276	0.621	0.241	0.729	p = 0.701
PSTOCK/EMP	0.462	1.319	0.447	1.723	p = 0.942
GROUP	0.684	0.466	0.678	0.469	p = 0.924
FOREIGN	0.293	0.456	0.224	0.418	p = 0.217
EXPORT	0.525	0.330	0.499	0.330	p = 0.546
$\hat{P}(X)$	0.312	0.166	0.312	0.166	p = 1.000
RD	1.292	3.563	0.518	1.213	p = 0.010
RDINT	4.370	8.202	2.208	4.653	p = 0.006
ln(*RD*)	-2.142	3.073	-3.996	3.988	p< 0.001
ln(*RDINT*)	-0.155	2.436	-1.624	2.962	p< 0.001

a) 12 industry dummies not reported.
b) t-statistics are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group.

This holds for both the full sample and subsamples of innovating firms. E.g. when the full sample is considered, the treated firms spend about 100% more on R&D compared to the situation where there would not have been public policy programs in place. If, however, only innovating companies are considered, the treated firms spend about 53% more. Those results show that Flemish R&D policy is not subject to full crowding-out effects in the business sector – a result that has been found, for example, on the US SBIR project by Wallsten (2000). The results found in Flanders are actually in line with recent studies on other European countries.

Additionality in the policy mix

Besides input additionality, the effects of various instruments in the policy mix need further investigation. In order to evaluate the impact of the current policy mix, we use caliper matching to firm-level data to account for a potential selection bias. In the studies taken into account (Czarnitzki and Lopes-Bento, 2014) to integrate policy mix effects on additionality, it is found that EU grants and national grants, as well as the combination of both, lead to higher innovation input in the economy when compared with a situation where these policies would be absent, that is, the counterfactual situation where the recipient firms would not be funded. The authors show that full crowding-out can be rejected for both types of grants. In addition, no evidence is found that one policy is crowding-out the effect of the other as recipients that obtain funding from both sources always invest more into innovation and R&D than in the counterfactual situation of just receiving funds from a single source. Based on the policy mix taken into account in this review section, we can conclude that we do not find evidence that project management impacts the effect of the support received. A summary overview of the main results of this study (Czarnitzki and Lopes-Bento, 2014) is summarized as follows:



	Dependent variable: R&D Intensity (R&D expenditures/sales × 100) Actual status (m)			
Counterfactual (*l*)	No funding	Only national funding	Only EU funding	Funding from both sources
No funding		*Case 1* 2.850***	*Case 2* 2.787***	*Case 3* 8.288***
Only national funding	*Case 7* − 2.055***		*Case 4* 0.061	*Case 5* 4.218***
Only EU funding	*Case 8*	*Case 9*		*Case 6*
Funding from both sources	*Case 10* − 6.479***	*Case 11* − 4.575***	*Case 12* − 5.612***	

	Dependent variable: innovation intensity (innovation expenditures/sales × 100) Actual status (m)			
Counterfactual (*l*)	No funding	Only national funding	Only EU funding	Funding from both sources
No funding		*Case 1* 3.422***	*Case 2* 4.061***	*Case 3* 8.663***
Only national funding	*Case 7* − 2.909***		*Case 4* 0.429	*Case 5* 3.587***
Only EU funding	*Case 8*	*Case 9*		*Case 6*
Funding from both sources	*Case 10* − 7.165***	*Case 11* − 4.439***	*Case 12* − 4.777***	

Notes: Standard errors are in parentheses. ***, **, * indicate a 1 per cent, 5 per cent, and 10 per cent significance level, respectively. Standard errors are obtained with Lechner's (1999) asymptotic approximation correcting for replicated observations due to sampling with replacement. Cases 10 and 11 were matched using a caliper threshold to avoid bad matches and in addition for case 11 ln *AGE* and ln *EMP* were used as additional matching criteria in order to properly balance treatment group and control group.

It can be seen in cases 1 – 3 that getting subsidies (be it from national sources, from EU sources or from both sources cumulated) has a positive effect on R&D and innovation intensity of the recipient firms compared with not getting subsidies at all. For all three cases, the outcome variables are significant at a 1 per cent level, and the null hypothesis of full crowding-out can hence be rejected.

Cases 7 and 10 consider the opposite case, that is, a "treatment on the untreated". These two cases ask the question whether non-subsidized firms would have benefited from a treatment if they had gotten a subsidy from either national sources or both national and European sources. Here, significant negative results are found, that is, non-funded firms would have indeed invested more into R&D and innovation if they had gotten public support.

While the above-mentioned results are in line with most of the literature, one can now turn to the more interesting and not yet investigated cases so far, that is, the different impacts of heterogeneous treatments within beneficiaries of different policies. The cases 4 and 5, for instance, benchmark the impact of EU policies compared with national policies. While no significant differences are found in the effect between receiving funds from the EU and funds from the national government (i.e. the recipient would have invested similarly if he would have received money from the national government rather than from the EC; case 4), we find that when national subsidies are combined with EU money, the recipients invest more than in the counterfactual situation of only getting a national subsidy. The latter finding (i.e. the significant result of case 5) rejects the hypothesis of crowding-out effect between different funding sources. Recipients of grants from both sources invest more compared to the counterfactual situation of getting funding only from the national authorities.[1]

Accordingly, significant treatment effects are also found in cases 11 and 12 where the authors investigated whether single source recipients would have potentially benefited from a further treatment. Firms that got funding from only one source would have benefited from supplemental funding of the other source. This reinforces the conclusion that (full) crowding-out between the funding schemes can be rejected.

With regard to innovation performance, the study did not find that publicly funded firms are less productive. Keeping innovation investment constant allows to indirectly conclude that the granted research projects have a similar productivity as purely privately funded projects. In terms of future patenting activity, it is found that nationally funded firms (only national or in combination with EU funds) are more likely apply for patents in future time periods.

A subsequent citation analysis further allows concluding that the patents filed by subsidized firms are more often referred to as relevant prior art. The filed patents therefore do not only reflect the compliance to the funding agency's rules. These findings are particularly interesting in light of the program management insofar that the selection process by the agencies does not reveal systematic differences. No evidence is found pointing to the fact that EU-funded projects are less productive than the national or exclusively privately funded projects.

Output additionality

So far, the main focus in the literature has been on input additionality of R&D grants, while only some studies assess their impact on output. Rarely, the interrelated nature of these input and output stages has been accounted for by using a simultaneous equation model. Consequently, this section reviews a more structural approach in order to integrate both stages into one econometric model. This is done by applying a conceptually new variant of the Crépon–Duguet–Mairesse (CDM) framework (Czarnitzki and Delanote, 2015). The resulting model allows to estimate input and output additionality effects of subsidies and, in particular, whether subsidized projects generate a discount or premium in terms of innovation outcome when compared to the non– subsidized, i.e. purely privately financed, projects. They estimate a three-equation recursive system of equations using econometric control function approaches, i.e. instrumental variable techniques.

Some selected results obtained by Czarnitzki and Delanote (2015) are described in the table below.

---

[1] Cases 6, 8 and 9 could not be analyzed due to a lack of data.

The first column presents results when the calculation of the R&D variables is based upon internal R&D intensity (RDint) and column 2 when this is based upon total R&D intensity (RDtot), i.e. internal and external R&D. Results show that the private part of both total R&D expenditures and internal R&D expenditures has a positive and significant effect on innovation output as reflected by the coefficient of RDint and RDtot respectively. Further analyses (not presented here in more detail) show that the subsidy-induced R&D investment has a positive significant effect on output. Finally, the hypothesis that privately financed R&D and subsidized R&D have equal marginal productivity effects is statistically not rejected. In sum, results point to a positive significant effect on innovation output of both purely private and subsidy-induced R&D. Furthermore, no evidence of a lower effect of this latter component compared to privately financed R&D in terms of generated sales due to new products has been found.

The results of this approach largely confirm insights of the input additionality literature, i.e. public subsidies complement private R&D investment. In addition, results point to positive output effects of both purely privately funded and subsidy–induced R&D. Furthermore, no evidence is found of a premium or discount of subsidy–induced R&D in terms of its marginal contribution on new product sales when compared to purely privately financed R&D.

Overview results on output additionality by Czarnitzki and Delanote (2015):

	Output Equation	
	(1)	(2)
RDint	3.559**	
	(1.641)	
RDtot		3.410**
		(1.571)
IWTSUBINT	-3.883	-5.212
	(4.449)	(4.566)
lnEMP	0.878	0.757
	(0.593)	(0.622)
PSnew	-17.320	-39.239
	(76.823)	(78.217)
PSnew2	-11.087	59.380
	(194.907)	(230.117)
EXPORT	2.574*	2.506
	(1.551)	(1.588)
GP	-1.526	-1.752
	(1.200)	(1.361)
FOREIGN	-1.072	-1.315
	(1.477)	(1.521)
lnAGE	-0.832	-0.798
	(0.794)	(0.873)
Constant	3.853	4.273
	(3.363)	(3.394)
N	2472	2472
Bootstrap replications	200	
β_2	2.048**	1.699**
	(0.960)	(0.772)
γ_2 (=discount/premium)	-0.425	-0.502
	(1.992)	(0.660)
$\hat{\varepsilon}_3$	-0.623	0.632
	(2.521)	(2.617)
$\hat{\varepsilon}_2$	-2.801*	-2.765*
	(1.638)	(1.569)
Test on joint significance of		
- Industry	$\chi^2(11) = 44.32$***	$\chi^2(11) = 45.50$***
- Time	$\chi^2(2) = 3.08$	$\chi^2(2) = 2.92$
- Region	$\chi^2(4) = 3.29$	$\chi^2(4) = 3.32$

Standard errors in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Conclusion: input – output – mix

The considerations outlined in the previous sections demonstrate that the measurement and mapping of additionality effects requires a comprehensive approach in terms of methods and indicators. In this overview, we tried to give a current synthesis of a consistent approach to map and measure additionality effects of public R&D policy. In doing so, we strive to present to policy makers a coherent and consistent framework to assess major effects of the policies they design and implement.

It is clear that the use of appropriate econometrics methods increased significantly in the last decades. However, further steps can and need to be made. Current insights often are only partially relevant to policy makers. Yes, we can show positive treatment effects, but many questions remain. More useful information could be offered by providing insights into questions as “How can we make the program better, i.e. more effective and/or more efficient?“ In order to do so, we should search for heterogeneous treatment effects, e.g. Czarnitzki and Lopes-Bento (2014).

There also still is room for improvement with respect to „identification“, e.g. we should exploit discontinuities, instruments and experiments. In doing so, we may apply methods in a more useful way for policy making (i.e. moving beyond homogenous „treatment effects on the treated“ of a single program), thus assisting both with the design of policy schemes and the selection of policy schemes.

References

Aerts, K. and D. Czarnitzki (2006), Evaluation of R&D Policy, the Case of Flanders, *Policy Report to the Flemish Government*, ECOOM.

Arrow, K. (1962), Economic Welfare and the Allocations of Resources of Invention, in: Nelson, R.R. (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton.

Arrow, K.J. and R.C. Lind (1970), Uncertainty and the Evaluation of Public Investment Decisions, *American Economic Review*, 60, 364-378.

Arrow, K.J. (1996), The Economics of Information: An Exposition, *Empirica* 23(2), 119-128.

Arrow, K.J. (1999), Information and the organization of industry, in: G. Chichilnisky (ed.), *Markets, Information, and Uncertainty*. Essays in Economic Theory in Honor of Kenneth J. Arrow, Cambridge: Cambridge University Press, pp. 19-25.

Busom, I. (2000), An empirical evaluation of the effects of R&D subsidies, *Economics of Innovation and New Technology* 9(2), 111-148.

Czarnitzki, D. and J. Delanote (2015), Incorporating Innovation Subsidies in the CDM Framework: empirical Evidence from Belgium. Forthcoming in: *Economics of Innovation and New Technology*.

Czarnitzki, D. and H. Hottenrott (2011), Financial Constraints: Routine versus Cutting Edge R&D Investment, *Journal of Economics and Management Strategy* 20(1), 121-157.

Czarnitzki, D., H. Hottenrott and S. Thorwarth (2011), Industrial Research versus Development Investment: The Implications of Financial Constraints, *Cambridge Journal of Economics* 35(3), 527-544.

Czarnitzki, D. and K. Hussinger (2004), The Link between R&D Subsidies, R&D Spending and Technological Performance, *ZEW Discussion Paper No. 04-56*, Mannheim.

Czarnitzki, D. and G. Licht (2006), Additionality of Public R&D Grants in a Transition Economy: The Case of Eastern Germany, *Economics of Transition* 14(1), 101-131.

Czarnitzki, D. and C. Lopes-Bento (2011), Evaluation of Public R&D Policies: A Cross-Country Comparison, *World Review of Science, Technology and Sustainable Development*, forthcoming.

Czarnitzki, D. and C. Lopes-Bento (2014), Innovation Subsidies: Does the Funding Source matter for Innovation Intensity and Performance, *Industry and Innovation*.

Czarnitzki, D. and A.A. Toole (2007), Business R&D and the interplay of R&D subsidies and product market uncertainty, *Review of Industrial Organization* 31(3), 169-181.

Czarnitzki, D. and A.A. Toole (2011), Patent Protection, Market Uncertainty, and R&D Investment, *Review of Economics and Statistics* 93(1), 147-159.

David, P.A., B.H. Hall and A.A. Toole (2000), Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, Research Policy 29(4-5), 497-529.

DG Competition (2016), How evaluation can help: the case of financial support to business R&D&I, *Policy brief 2016-03*, May.

Dixit, A.K. and R.S. Pindyck (1994), Investment under Uncertainty, *Princeton Univ. Press*, Princeton, NJ.

Griliches, Z. and J. Mairesse (1984), Productivity and R&D at the firm level, in: R&D, *Patents and Productivity*, Griliches Z (ed.). University of Chicago Press: Chicago, IL; 339–374

Griliches Z. (1990), Patent Statistics as Economic Indicators: A Survey, *Journal of Economic Literature* XXVIII, 1661–1707.

Hall, B.H. (2002), The financing of Research and Development, *Oxford Review of Economic Policy*, 18, 35-51.

Hall, B.H. and J. Van Reenen (2000), How effective are fiscal incentives for R&D? *Research Policy* 29, 449-469.

Lach, S. (2002), Do R&D subsidies stimulate or displace private R&D? Evidence from Israel, *Journal of Industrial Economics* 50(4), 369-390.

Lamberton, D. M. (1996), ‘Introduction: ‘Threatened Wreckage’ or New Paradigm?’, in Donald M.

Lamberton (Ed.), *The Economics of Communication and Information*, Cheltham UK and Brookfield US: Edward Elgar, pp. xiii-xxviii.

Nelson, R.R. (1959), The Simple Economics of Basic Scientific Research, *Journal of Political Economy* 49, 297-306.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*, Harper and Row, New York.

Wallsten, S.J. (2000), The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research Program, *RAND Journal of Economics.*