International Journal of Industrial Organization 31 (2013) 634–642

Contents lists available at ScienceDirect

International Journal of Industrial Organization

journal homepage: www.elsevier.com/locate/ijio

Market failures and the additionality effects of public support to private R&D: Theory and empirical implications[☆]

Tuomas Takalo [a,c], Tanja Tanayama [b], Otto Toivanen [c,*]

[a] Bank of Finland, Snellmaninaukio, 00170 Helsinki, Finland
[b] National Audit Office of Finland, Antinkatu 1, Helsinki, Finland
[c] KU Leuven, Department of Managerial Economics, Strategy and Innovation, Naamsestraat 69, B-3000 Leuven, Belgium

ARTICLE INFO

Available online 27 February 2013

JEL classification:
D04
G38
H25
L59
O31
O38

Keywords:
Additionality
Financing of innovations
Market failure
R&D investments
Subsidies
Welfare

ABSTRACT

We extend the theoretical basis of the empirical literature on the effects of R&D subsidies by providing an estimable model of strategic interaction among subsidy applicants, and public and private sector R&D financiers. Our model incorporates fixed R&D cost and a cost of external finance. We derive the optimal support rule. At the intensive (extensive) margin the costs of external funding reduce (increase) the optimal subsidy rate. We also establish necessary and sufficient conditions for the existence of additionality. It turns out that additionality at the intensive margin is less likely with higher spillovers. Our results suggest that the relationship between additionality and welfare may not be straightforward.

1. Introduction

It is widely acknowledged that private sector investments in innovation are crucial for the enhancement of economic growth and welfare. Nevertheless, the private sector is likely to invest sub-optimally in R&D because of appropriability problems and potential market failures in the provision of private funding to R&D. To stimulate private R&D investments, governments around the world are increasingly spending public funds in direct R&D subsidies and tax incentives. These innovation polices have a central role in virtually all developed countries.[1] For example, all OECD countries use direct R&D subsidies, and increasingly many offer some form of R&D tax incentive (Busom et al., 2012; OECD, 2011; and Warda, 2006). Both innovation support policies are also becoming more widespread in emerging countries: e.g., India uses both subsidies and tax incentives.

A large empirical literature has contributed to our understanding of how these policies work: the R&D subsidy literature is surveyed, e.g., by David et al. (2000), Garciá-Quevedo (2004), Cerulli (2010), and Zúñica-Vicente et al. (forthcoming), and the R&D tax credit literature by Hall and van Reenen (2000), Parsons and Phillips (2007) and Mohnen and Lokshin (2010). The research effort has largely focused on the question of whether or not there is additionality, i.e., whether public support increases private R&D investment rather than crowds it out.

While the basic theoretical motivation for government support to private R&D has been well understood for at least half a century (Arrow, 1962, and Nelson, 1959), the empirical literature is generally not based on theoretical models capturing the strategic decisions by firms, government agencies, and private sector financiers of R&D that constitute an essential part of an innovation policy environment. Takalo et al. (forthcoming) model the firm's decision to apply for a subsidy, the government's decision on the level of support, and the firm's subsequent R&D investment. In this paper, we extend that model to include fixed costs of R&D projects, and a possibility to tap financial markets for R&D funding at a cost. These extensions allow us to provide

☆ We would like to thank two anonymous referees and the seminar audience at EARIE 2012 for comments, and Isabel Busom, Jeff Campbell, Jordi Jaumandreau and Manuel Trajtenberg for discussions. We also wish to thank the EU Seventh Framework Programme under grant agreement 290597 for SIMPATIC, and Tekes for financial support. The usual disclaimer applies.
* Corresponding author.
E-mail addresses: tuomas.takalo@gmail.com (T. Takalo), tanja.tanayama@kotikone.fi (T. Tanayama), otto.toivanen@econ.kuleuven.be (O. Toivanen).

[1] In this paper, innovation or R&D support policies refer to R&D subsidies and tax incentives, although the set of innovation policies include a variety of other instruments such as intellectual property rights and prizes. See Takalo (2012) for a review of the instruments for innovation policy and their justifications.

http://dx.doi.org/10.1016/j.ijindorg.2013.02.002

insights both into the role of different market failures and additionality in innovation policy design, and into the existing results in the literature, and should be helpful in new empirical investigations on innovation policies.

A generic form of the equation typically estimated in the literature is

$$g(R) = \mathbf{X}\beta + f(s)\delta + \epsilon \tag{1}$$

where the outcome variable $g(R)$ is often either directly the R&D investment (R) or its logarithm ($\ln R$), $\mathbf{X}$ is a vector of control variables with β being the associated vector of coefficients, $f(s)$ is a function of the public funding of R&D (which comes either in the form of direct subsidies or tax incentives) and s is the support (subsidy, tax incentive) rate, i.e., the fraction of R&D paid from public funds, and ϵ is a stochastic error term.[2] The main interest has been in the estimation of δ in Eq. (1). The main challenge has been the endogeneity of R&D support policies, which is mainly generated by nonrandom participation in R&D subsidy and tax incentive programs arising from both nonrandom assignment of government support and from self-selection into these support programs.[3]

The literature has used various ways to overcome the endogeneity problem (see Cerulli, 2010, for a review of the methods). Popular ways are instrumental variables and selection models (e.g., Busom, 2000; Hussinger, 2008, and Wallsten, 2000), differences-in-differences (e.g., Lach, 2002), matching and other non-parametric methods (e.g., Almus and Czarnitzki, 2003, and Czarnitzki et al., 2011). Structural econometric and other theory-based models are used less often, but some exist (e.g., Bloom et al., 2002; González et al., 2005; Lokshin and Mohnen, 2011, and Takalo et al., forthcoming).

One important feature missing from the structural econometric models of innovation policies is the interaction between public and private financiers of R&D intensive firms.[4] In this paper, we introduce a competitive financial sector funding R&D into the model of Takalo et al. (forthcoming). This is a simple way to model the costs of (private sector) external funding of R&D. We also add fixed costs of R&D, which determine the effects of R&D support policies at the extensive margin where the firms decide whether or not to invest in R&D. It is widely thought that policies generate larger additionality at the extensive margin than at the intensive margin where firms conducting R&D decide how much they invest (see, e.g., Einiö, 2009). We also use a more general form for the firm's profit function which allows an analysis of the effects of the firm's production technology.

We characterize the optimal subsidy policy in the presence of both fixed costs and external funding costs. We find that an increase in the fixed cost of R&D or in external financing cost may lead to lower or higher subsidies depending on parameter values. The government needs to give a higher subsidy to get the project implemented when fixed costs increase. An increase in the cost of external finance further raises the required subsidy at the extensive margin. But the costs eventually become so high that it is better not to subsidize the project even if the project is then not executed. In addition, we find that an increase in the cost of external finance leads to a *reduction* in the optimal subsidy rate at the intensive margin as a higher cost of finance dampens the firm's response to the subsidy.

We also establish necessary and sufficient conditions for the existence of additionality and for additionality to lead to a welfare improvement. It turns out that the projects generating large spillovers which optimally receive large subsidies are less likely to generate additionality at the intensive margin.

We present the model in the next section. In Section 3, we solve the model and characterize equilibria. In Sections 2 and 3, we also show how to derive estimation equations from our model, some of which are familiar from the existing literature. This econometric model is summarized in Section 4. In Section 5, we briefly discuss the implications of our model for the rationales of R&D support policies, additionality, its relation to welfare, and the interpretation of additionality results of the empirical literature. Section 6 concludes.

2. The model

We consider a four-stage game of incomplete information among a firm with an R&D project, a public agency that gives R&D subsidies, and private sector financiers offering funding for R&D. Henceforth, we refer to the public agency simply as "the agency" and to the private sector financiers as "financiers" when no confusion may arise. The R&D project involves both a variable investment and a fixed cost. For brevity, we assume the firm has no funds of its own and one project per firm.

Timing of events. In stage one, the firm decides whether or not to apply for a subsidy for an R&D project. If the firm applies, in stage two, the agency evaluates the proposed project, and decides the level of the subsidy, which amounts to a credible promise to reimburse ex post a share of the variable R&D investment costs. In stage three, financiers compete to supply the rest of the needed project funding. In stage four, the firm decides the level of its R&D investment. If the firm invests, and has been granted a subsidy in stage two, it will be reimbursed accordingly. Finally, the project returns are realized, and divided according to the financing contract made in stage three.

Assumptions. Our goal is to build a model that not only delivers theoretical insights but that can also be estimated. We therefore use more specific functional forms than would be necessary from a purely theoretical point of view. Assumptions on functional forms are introduced as we proceed.

We make two key informational assumptions. First, the type of the firm is common knowledge. This avoids complexities arising from signaling games.[5] Second, the type of the public agency is unknown to the firm when it contemplates the subsidy application. The firm only knows the distribution of the agency type. As will be made more precise in Section 2.4, the agency's type is about how it values the project of the firm beyond the profits the project generates. It may be helpful to think of these benefits as spillovers.

The latter informational assumption in essence introduces uncertainty on the firm's side about the agency's valuation of its projects when contemplating an application. This ensures, in line with empirical evidence, equilibrium outcomes where a firm submits a costly subsidy application only to be turned down. Since in our model the agency cannot signal its type to a potential applicant, it is immaterial whether the type of the agency is private information or whether there is symmetric but incomplete information. We opt for the simpler and arguably more realistic assumption that the agency learns its type after receiving and screening an application, i.e., symmetric but incomplete information regarding the agency's type prevails at the application stage.

Compared to standard corporate finance models, where often a borrower's type is private information and hence unknown to a (private sector) lender, these two informational assumptions may

[2] One could also write $f(R(s), s)$ as some empirical applications use the monetary amount of the subsidy as an endogenous explanatory variable.

[3] For example, in the Spanish data used by Busom et al. (2012), only 12% of SMEs and 20% of large firms investing in R&D use both subsidies and tax credits. 23% of SMEs and 17% of large firms invest with the help of subsidies only, and 17% of SMEs and 26% of large firms only use tax credits. The rest invest without either form of support.

[4] Gelabert et al. (2009) and Busom et al. (2012) study the interaction empirically, and Keuschnigg and Ribi (forthcoming) and Takalo and Tanayama (2010) theoretically but to the best of our knowledge there exists no structural econometric model besides our ongoing work (Takalo et al., 2010) that would incorporate both private and public sources of R&D funding.

[5] See Takalo and Tanayama (2010) for a model where a subsidy decision by the agency acts as a signal about the firm's type for financiers.