Energy Policy 113 (2018) 430–438

Contents lists available at ScienceDirect

Energy Policy

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

The firm-level innovation impact of public R&D funding: Evidence from the German renewable energy sector

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ARTICLE INFO

Keywords:
Public policy, R&D funding
Innovation
Renewable energy

ABSTRACT

Drawing on a resource-based view (RBV), this paper analyzes the effect of public R&D funding as a financial resource on firm-level R&D performance. The panel regression analysis focuses on the German renewable energy sector and is based on 206 publicly granted R&D projects with a volume of 235 Mio €, approx. 3900 patents and 8500 patent citation data for 1448 firms. It verifies a significant positive effect of public R&D funding in terms of absolute monetary value and past funding intensity on the number of patents, but no significant effect on patent's quality measured by the number of citations. Besides public R&D funding, a firm's technology knowledge base and the overall financial situation have a positive effect on the quantity of patents, while the effect of firm's age is negative. The paper contributes to the RBV by linking it with extant research on firm innovation, gaining empirical insights on the importance of financial, physical and intangible resources. The paper encourages innovation managers to apply for public R&D funding and invest constantly in a firm's technology knowledge base.

1. Introduction

Although the origin of the resource-based view (RBV) is found in strategic management literature (Barney, 1986, 1991; Wernerfelt, 1984), its linkage to research on firm-level innovation is of high scientific interest and has two important practical implications. First, the RBV supports innovation managers in identifying critical firm resources in order to maximize R&D performance and thus gain competitive advantage. Second, the RBV gives recommendations on how to finance critical firm resources. Besides internal financial resources, an innovation manager can leverage a variety of external financial resources, e.g., bank loans, stock market financing, venture capital, and crowd funding.

While the relevance of financial resources for firm-level R&D performance has been discussed in the context of the RBV (e.g., Del Canto and Suárez-González, 1999; Galbreath, 2005; Lee et al., 2001), the role of public R&D funding has been neglected. This neglect is surprising as 28% of the gross domestic expenditure on R&D in 2014 within OECD-countries is spent by governments.[1] Furthermore, Nelson (1959) and Arrow (1962) highlighted the need for public R&D support decades ago: private firms do not invest in R&D projects at a socially desirable level as they cannot fully leverage the economic potential internally due to knowledge spillovers. Principal-agency theory gives evidence that the type of financing has an impact on R&D performance. While asymmetric information, uncertainty about the R&D outcome, and limited control over the innovation process hinder R&D activity; flexible financial structures, culture of feedback and failure, focus on long-term success, and responsibility at the firm level all foster innovation (Bergemann and Hege, 2005; Holmstrom, 1989; Manso, 2011). The lack of granular grant data on the firm-level is a major reason why the effect of public R&D funding on firm-level R&D activity has not yet been fully explored (Belitz and Lejpras, 2016; Bérubé and Mohnen, 2009; Clausen, 2009).

On the other hand, there is a rich set of macro-economic studies on the effectiveness of public R&D funding for the energy sector (e.g., Bointner, 2014; Johnstone et al., 2010; Klaassen et al., 2005; Peters et al., 2012). This research uses public R&D funding as an aggregated input factor to explain accumulated R&D outcome (e.g., patent stock, installed capacity, learning curves) on a macro level, with countries or sectors as the unit of analysis. The RBV, however, emphasizes the firm's heterogeneity within the innovation process (Barney, 1991), which requires a more granular firm-level approach of analysis. Oliver (1997) links RBV and institutional theory, thereby underlining the importance of firm analysis since the strategic reactions of individual firms towards institutional influence differ.

These research gaps lead to two questions. (1) What role does public R&D funding as a financial resource have on firm-level R&D performance? (2) What other critical firm resources are key success factors for firm innovativeness?

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[1] Source: OECD Research and Development Statistics (www.oecd.org/sti/rds).

https://doi.org/10.1016/j.enpol.2017.11.031
Received 4 August 2017; Accepted 14 November 2017
Available online 23 November 2017
0301-4215/

To answer these questions, we derive hypotheses from the RBV and add empirical insights from prior studies on the effectiveness of public R&D funding. In particular, we use negative binomial and GLS panel regression models to measure the effect of financial, physical, and intangible resources on firm-level R&D performance for 1448 German renewable energy firms. Our dataset consists of 206 publicly granted projects for the German photovoltaic (PV) and wind sectors, with a volume of approx. 235 Mio € between 2006 and 2015. We analyze approx. 3900 patents and 8500 patent citation data to evaluate individual firm-level R&D performance. First, our findings show that public R&D funding, a higher past funding intensity, and a firm's overall financial situation have a significant positive effect on the quantity of firm-level innovation activity in terms of patent count but not on their technological or economic value measured by patent citation data. Second, a firm's technological knowledge base as an intangible resource has a significant positive effect on both patent quantity and quality, while total assets as an indicator for physical resources have no significant effect.

Our findings contribute to linking RBV and innovation research by exploring whether public R&D funding can serve as a financial resource to promote innovation. Four different contributions are of great interest. First, previous studies on financing innovation focus primarily on equity, bank loans, or venture capital, and neglect public R&D funding (Hall and Lerner, 2010), especially in empirical studies (Howell, 2017). As the cost and incentive structure of public R&D funding is different, we provide practical implications on effective R&D financing. Second, we not only explore public R&D funding as a critical firm resource for innovation, but also a firm's overall financial situation, its accumulated technology knowledge base, and the amount of physical resources. This is highly relevant as Galbreath (2005) attaches importance to using a comprehensive set of resources rather than isolated ones. Third, our research effort enables us to use granular data on firm resources, firm-level R&D performance, and public R&D funding data compared to the primarily more aggregated approach of previous research where the main focus was on evaluating different policy instruments (e.g., Johnstone et al., 2010; Olmos et al., 2012; Polzin et al., 2015) and crowding-out effects (e.g., Clausen, 2009; Dimos and Pugh, 2016; González and Pazó, 2008). Fourth, the institutional nature of public R&D funding and its empirical application to the German renewable energy sector contributes to the literature on energy technology innovation systems (Gallagher et al., 2006, 2012; Grübler et al., 2012). It advances new knowledge within one of its core research gaps: the interaction of actors and institutions in the innovation process.

This paper offers corporate innovation managers insights into the trade-off between the benefit of public financial resources for firm's R&D activities and the required efforts for the grant application and documentation as well as the disclosure of project results. In addition, it defines key success factors for developing innovations in the field of renewable energy technologies. The practical implications for politicians are recommendations for a funding scheme tailored towards the resources of renewable energy firms and therefore an efficient usage of public money.

2. Theory and hypotheses

2.1. RBV as a theoretical foundation to explain superior firm's R&D performance through heterogeneous financial resources

The core question of our paper is whether and how public R&D funding as a specific financial resource affects a firm's R&D performance. The widely recognized Modigliani-Miller theorem (Modigliani and Miller, 1959, 1961) claims that a firm's financial structure should not affect its R&D investments; however, asymmetric information and moral hazard between the inventor and investor as well as tax considerations reflect the practical limitations of the theorem (Hall and Lerner, 2010). We base our argumentation on the RBV, as it gives clear guidance on how to evaluate distinctive firm resources and to explain superior firm performance.

Penrose (1959) laid the foundations for the RBV by defining a firm as a bundle of resources and emphasizing their heterogeneity. Wernerfelt (1984), Barney (1986, 1991),and Dierickx and Cool (1989) applied this idea to the question of how firms can generate competitive advantage and why their performance differs. Despite the lack of a conclusive definition in the literature, we define resources as tangible and intangible assets that enable a firm to implement its strategy (Barney and Arikan, 2006). Tangible resources consist of financial assets (e.g., equity, debt, and retained earnings) and physical assets (e.g., buildings, equipment, machines). Intangible resources are related to a firm's human capital (e.g., knowledge, skills, relationships) and organization (e.g., reputation, culture, internal reporting structures) (Barney and Arikan, 2006). This internal strategy focus of the RBV stands in stark contrast to the external perspective of “Porter's Five Forces Model” (Porter, 1979), which explains a firm's strategy in the context of its surrounding industry characteristics. Decisions under uncertainty, a rapidly changing external environment, fading industry boundaries, and the importance of knowledge, organization and culture are arguments in favour of the RBV and against primarily static environmental models.

Dosi (1988) was one of the first scholars to apply this shift from an external towards an internal perspective to firm-level innovation. Inventions are not per se the result of external influences and industry characteristics, nor do they occur by evaluating competitor's technology base and potential market opportunities. Instead, a firm's resources are a critical source for innovation. Among these resources, Dosi (1988) and further scholars (e.g., Del Canto and Suárez-González, 1999; Grant, 1996) highlight the important role of knowledge in explaining the heterogeneity of a firm's R&D performance, while the role of financial resources is of minor relevance. We, however, apply criteria from the RBV to evaluate a resource (Barney, 1991; Barney and Arikan, 2006) in the next section and show that public R&D funding does have the potential to explain differences in R&D performances.

2.2. Absolute monetary value of public R&D funding

Public R&D funding is rare among competing firms as the public R&D budget is limited and the demand for R&D grants exceeds the supply (Bronzini and Iachini, 2014; Howell, 2017). It is non-substitutable in the sense that other financial sources are less cost-efficient than a public R&D grant. Besides the costs for the grant application and project documentation, there are no additional capital costs to compensate financiers for project risks and information asymmetries. It is imperfectly imitable as only few competitors fully recognize its role in the innovation process and, secondly, fulfil the funding conditions. It is inelastic in supply as an additional demand for R&D grants does not lead to an additional supply. Arguments for why public R&D funding is a valuable resource refer to (a) R&D personnel, (b) R&D working conditions, (c) R&D project portfolio, and (d) a firm's reputation. Public R&D funding enables a firm to not only hire more R&D personnel but also to attract better-qualified scientists. Examples of how public R&D funding materializes for R&D working conditions, include better-equipped laboratories, enhanced stocks of raw materials, and improved access to databases, amongst others. In terms of the R&D project portfolio, the public nature of grants should enable innovation managers to invest in riskier R&D projects due to lower personal career risks (Aghion et al., 2013) and relatively low capital costs. In addition, public R&D funding facilitates market-based financing (Takalo and Tanayama, 2010) and in the case of early stage grants, raise the probability of venture capital investment (Howell, 2017) as the grant itself reduces the required credit amount and implies good project quality, both of which lower the risks for financiers. Public R&D funding increases a firm's reputation and its institutional network, which facilitates national and global R&D cooperation with research institutes, suppliers,