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Complementarities of innovation activities: An empirical analysis of the German manufacturing sector

Claudia Schmiedeberg*

University of Hamburg, Von-Melle-Park 5, 20146 Hamburg, Germany

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ABSTRACT

Innovation strategies in manufacturing often involve internal R&D activities as well as external partnerships. Thereby it is not clear if internal and external activities are complements or substitutes. This paper tests for complementarity of different innovation activities, i.e. internal R&D, R&D contracting, and R&D cooperation. The empirical analysis of cross-sectional firm level data of the German manufacturing sector comprises both indirect and direct complementarity tests; it is based on data from the German part of the Community Innovation Survey (CIS 3). The results provide evidence for significant complementarities between internal R&D and R&D cooperation, but cast doubt on the complementarity of internal and contracted R&D, since a productivity effect on firms' patenting probability or sales with new products cannot be found.

1. Introduction

Innovation persistently attracts the attention of both economists and politicians as a driver of competitiveness and firm performance (Lachenmaier, 2007). The importance of innovation is reflected by considerably increasing innovation expenditures, observed across countries and industries: in Germany, for instance, total business R&D expenditure has risen by 54.5% in the period 1995–2004 (Stifterverband, 2006); in the European Union the annual increase in this period was 3% (OECD, 2007). R&D is not a perfect indicator for innovation given the existence of innovation activities other than R&D, but a large part of innovation is based on R&D (Crepon et al., 1998). However, R&D can be organized in different ways, be it in-house R&D activities, sub-contracting of R&D projects or R&D cooperation with scientific institutes or other companies. Thus, innovation strategies are highly firm-specific and complex, often including both internal innovation activities and the involvement of external R&D partners (Nooteboom, 1999). Policy support (e.g. European Commission, 2005) is currently given in particular to partnerships in R&D due to their assumed advantages like efficiency gains due to the division of labor (Fritsch, 2004), cost and risk sharing (Love and Roper, 2004), the access to external knowledge or as well the control of outflowing knowledge (Cassiman and Veugelers, 2002a).[1] However, internal and external R&D activities are not independent from each other; they could

* Tel.: +49 40 42838 5565; fax: +49 40 42838 6361.
E-mail address: schmiedeberg@econ.uni-hamburg.de.

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[1] The role of internal and external R&D for innovation output has been investigated comprehensively; Faems et al. (2005) e.g. examine a sample of Belgian manufacturing firms and find a positive relationship between external R&D sourcing and innovative performance, confirming prior related studies (e.g. Stuart, 2000; François et al., 2002; Becker and Dietz, 2002; Chang, 2003; Rogers, 2004; Belderbos et al., 2004). Also the link between internal R&D and innovation output is well documented (Mansfield, 1981; Romijn and Albaladejo, 2002; Bhattacharya and Bloch, 2004).

be used as substitutes or complements in the innovation process. Both potential relationships have been investigated empirically, but conclusions are not clear cut (see literature review below).

Building upon the existing literature, this paper presents empirical evidence for complementarity of internal and external innovation activities in German manufacturing. It employs a twofold strategy, as used similarly by Cassiman and Veugelers (2002b, 2006), which comprises the search for correlation as well as for a direct productivity effect, using representative data drawn from the German part of the Community Innovation Survey (CIS 3) in 2000. Both R&D contracting and R&D cooperation and their complementarity to internal R&D are included in order to depict a comprehensive picture of the firms' innovation strategies. To my knowledge, regarding German manufacturing only complementarities between internal R&D and R&D cooperation have been investigated substantially (Becker and Peters, 2000; Love and Roper, 2001), whereas the relationship of internal and contracted R&D has been tested in detail so far only on the basis of Belgian data (Cassiman and Veugelers, 2002b, 2006). The case of multiple complementarities, i.e. between internal, contracted *and* collaborative R&D, is not considered in the analysis.

The paper is structured as follows: after a review on the existing empirical literature and an explanation of the conceptual framework and the mechanisms that drive complementarities in R&D in the following section, the methodology to measure complementarities is explained in Section 4. In Section 5, an overview of the used data from the Mannheim Innovation Panel and the implemented variables is given. Section 6 presents and discusses the empirical results, and Section 7 finally summarizes and relates the results to prior research.

2. Empirical literature on complementarities

If and to what extent the complementarities assumed by economic theory exist has been discussed in the literature since the nineties. But empirical research has not come to a clear conclusion yet: a large part of the literature concentrates on the relation of internal and external R&D as input factors to innovation. In particular the influence of internal R&D on R&D cooperation has been investigated at length. So, e.g. Abramovsky et al. (2005) find a positive impact of internal R&D on the probability of R&D cooperation for four European countries, confirming prior empirical results. Arora and Gambardella (1994) analyze pharmaceutical firms in the US, Colombo (1995) the number cooperation agreements of firms in IT industries; both studies present a significant correlation between internal R&D and R&D cooperation. Similar results are reported also by Cassiman and Veugelers (2002a) for Belgium, Bönte and Keilbach (2004) and Schmidt (2005) for Germany, Colombo et al. (2006) for high-tech startups in Italy, and López (2008) for Spanish manufacturing. Similarly the dependence of R&D contracting on internal R&D has been studied (e.g. Nakamura and Odagiri, 2005; Dhont-Peltrault and Pfister, 2007), as well as the opposite direction of causality, i.e. the influence of external linkages on internal R&D intensity (Veugelers, 1997; Harabi, 2002). Some authors refer to complementarity when explaining the link between internal and external R&D; however, the positive correlation between internal and external R&D does not necessarily imply complementarity of these activities.

Thus, to analyze the relationship in detail, more elaborate methods are used by a number of researchers: analyzing data of 1300 UK manufacturing plants, Love and Roper (1999) implement a three-step procedure which includes both the adoption of internal and external innovation activities, an endogeneity test for the input factors and the analysis of innovation output subject to innovation activities. Their results regarding the adoption of activities suggest that internal and external R&D are substitutes rather than complements, whereby they do not differentiate between R&D cooperation and sub-contracting. In addition, they show that both external R&D and the existence of a R&D department have a significant positive impact on innovation output. Conclusions on the effect of joint implementation of internal and external R&D, however, cannot be drawn from their analysis. In a later investigation, Love and Roper (2001) confirm these results for the UK and Ireland, without finding a clear substitute or complementary relationship in Germany, though. When directly testing the impact of joint implementation of internal and external R&D activities, however, R&D cooperation does not seem to have any influence on innovation output (measured as sales of new products) at all. Beneito (2006) focuses on R&D contracting, using a panel of Spanish manufacturing firms in the period 1990–1996. The results reveal a positive effect of contracted R&D when combined with internal R&D, pointing out the role of absorptive capacity. Based on the distinction between innovation types measured by patents and utility models, Beneito stresses a particular aspect of complementarity concluding that internal R&D produces rather significant innovation while contracted R&D is used for incremental innovation. Becker and Peters (2000) test the impact of university cooperations both on innovation input and output. They find a positive and significant influence of university cooperation on the intensity of in-house innovation activities as well as a complementarity effect of university cooperation and the regular conduction of R&D on patent production. R&D cooperation between firms and contracted R&D are not included in their investigation, though. Jirjahn and Kraft (2006) analyze if a firm's R&D intensity and its research cooperations are complementary regarding the production of product and process innovations and patents. They interpret their findings as a hint towards a rather substitutive relationship. Cassiman and Veugelers (2006) focus on the acquisition of external knowledge in comparison to in-house R&D activities and find complementarities between internal R&D and R&D contracting using data from 269 Belgian manufacturing firms. They analyze both the adoption of innovation activities and the impact of the (joint) implementation of the activities on innovation output. R&D cooperation is not considered in the investigation, however.

3. Main sources of complementarity in R&D

According to transaction cost theory firms are confronted with a make-or-buy decision regarding R&D