



The magnitude of innovation by demand in a sectoral system: The role of industrial users in semiconductors

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ABSTRACT

How relevant is innovation by demand compared to innovation by other actors in a sector? In quantitative terms, this is a yet unanswered question. The current study fills this major gap in the literature on industry studies. By taking a sectoral system perspective, this study is able to highlight the magnitude of innovation by intermediate user firms in a high technology sector: semiconductors. Using a combination of different datasets – patents, co-patents, R&D alliances and new ventures in semiconductors – this study proposes a novel quantitative approach to assessing the magnitude of innovative activity by user firms. The study reaches several findings. First, the magnitude of innovation by user firms, as measured by patents, is high in both absolute and relative terms compared to semiconductor firms and other actors in the sector. Second, the distribution of patents among different demand segments is highly uneven. Third, innovative user firms are highly heterogeneous in terms of size, diversification and vertical integration. Fourth, collaboration in R&D and co-patenting activity in semiconductors take place not just between user firms and semiconductor firms, but also among user firms themselves. Fifth, innovative user firms are quite active in entrepreneurial activity in semiconductors and their new ventures, on average, survive longer than spin-offs or other start-ups.

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1. Introduction

How relevant is innovation by demand compared to innovation by other actors in a sector? In quantitative terms, this is a yet unanswered question. The current study fills this major gap in the literature. By taking a sectoral system perspective and using a combination of indicators and datasets, this study examines the magnitude of innovation by intermediate users in a high technology sector: semiconductors.

Research on sectoral systems has shown that the innovation process involves interaction among a wide variety of actors for the generation and exchange of knowledge (Malerba, 2002). These actors may include the firms within the industry, linked firms such as equipment, component and material suppliers, consumers and users, universities, research organizations, financial institutions and other public and private organizations that interact in various ways within the broader sectoral system. The roles of these different actors and their importance for innovation vary according to the sector involved. Such observations have led researchers to

attempt to assess the contribution of these actors within a sectoral context. Much of this empirical work has focused on the relevance for innovation of producers, universities, and financial and public research organizations (see for example Mowery and Nelson, 1999; Malerba, 2004; Malerba and Mani, 2009). By contrast, little empirical work has been done within a sectoral systems perspective to date to assess the relevance of innovation by demand with respect to the other actors. As a result, the contribution of demand to innovation may be systematically underestimated by existing research (see the discussion by Lettl et al., 2009).

This comes as a surprise. In fact, in recent years a burgeoning literature has convincingly shown that demand, in terms of end-consumer users or intermediate user firms, plays an important role in affecting innovation in sectors. Broad studies on sectoral systems, such as the ones cited above, have also emphasized the active role of demand in sectors such as software, machine tools and semiconductors. In addition, since the pioneering work of von Hippel (1988, 2005) on lead users, numerous case studies and survey analyses have highlighted the major role of users in innovation processes across a variety of sectors. Yet despite these contributions, we still do not have clear ideas of the quantitative magnitude of innovation by demand at the sectoral level. A number of basic questions have yet to be answered. Within a sectoral system, how many innovations are developed by demand compared to other actors? What

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differences exist across different types and categories of demand? Does the magnitude of innovation by demand change over time? Answers to these questions are vital for both researchers and policy makers because they provide a quantitative indication of both the absolute and relative importance of innovation by demand within a sectoral system and lay the ground for comparative analyses of the relevance of demand across different sectoral systems.

The novelty of this study is to fill the gap in our understanding of the relative importance, in quantitative terms, of innovation by demand – defined here as *intermediate users* – in a sector. We will measure the magnitude of innovation by demand in one sector – semiconductors – through a series of indicators that will allow us to provide a quantitative analysis of the relevance of innovation by demand over time. After a brief discussion of what we know about the role of demand in innovation in different sectoral systems (Section 2), we present an analysis of the role of demand in the semiconductor sectoral system of innovation and introduce the four different indicators and data sets used in the study (Section 3). We then present the findings from our quantitative analysis (Section 4) of the extent and relative weight of innovation by demand in semiconductors over a 20-year period. Finally, in Section 5, we draw some conclusions.

2. Innovation by demand in a sectoral systems perspective: What we know and what we would like to know

Within the conceptual framework of a sectoral system, innovation and production are regarded as processes in which different types of actors are actively involved (Malerba, 2002). Demand, in terms of both end-consumers and intermediate user firms, is a major actor in such processes. Demand, alongside of suppliers, universities, and public and private research organizations, not only contributes to ideas and provides feedback for innovation, but also develops innovative solutions. The contribution of demand to innovation stems from its unique knowledge base with respect to other actors within a sectoral system: users and consumers have a better, deeper and more situated knowledge about uses, needs and applications.

Evidence of the role of demand in innovation comes from numerous sources. Over the past decades numerous sectoral studies have documented the role of demand in the innovation process. For example, Enos (1962) and Freeman (1968) pioneered some early work on the contribution of user innovations in the oil refining and chemical industries. Mowery and Nelson (1999) explored the sources of industrial leadership in seven industries across the United States, Japan, and Western Europe and showed that demand has played important roles in innovation in sectors as diverse as machine tools, software and computers. In a similar study, Malerba and Mani (2009) illustrated the major role of demand in developing economies in a range of industrial sectors such as ICT and software, capital goods industries and motorcycles.

These broad sectoral analyses have been complemented with a wide range of industry and case studies that explore the activities of specific user firms and user groups within sectors (Lundvall, 1992; Bogers et al., 2010). Much of this research stems from the seminal work by von Hippel (1988) on lead users. While playing different roles, users have been identified as important sources of innovation in sectors such as medical equipment (von Hippel, 1988), software (von Hippel, 2005), mountain biking and extreme sports (Schreier et al., 2007; Franke and Shah, 2003; Lüthje et al., 2006), automobiles and motorcycles (Sawhney et al., 2005) and banking services (Oliveira and von Hippel, 2011). In semiconductors, case studies on Samsung (Kim, 1997) and Ericsson (Glimstedt et al., 2010) documented the important contributions of vertically integrated user firms to innovation over the course of the industry's

life-cycle. Similarly, Ernst (2005b) discussed the role of demand in the recent evolution of the semiconductor industry, and von Hippel (1977) showed the importance of user innovation in semiconductor process machinery.

Another source of evidence on the role of demand in sectoral systems of innovation comes from the many surveys that have been conducted both within and across industries over the past years. Cross-industry surveys, such as those reported in the Sappho project (Rothwell et al., 1974) and by Myers and Marquis (1969) and Cohen et al. (2002) have confirmed the prominent role of demand in innovation. Along the same lines, the Community Innovation Surveys pointed to users as a major source of innovation (Belderbos et al., 2004a,b). In addition, many studies in business-to-business marketing have analyzed buyer-seller relationships in industrial markets in an attempt to show the contribution of buyers to the process of product development through both formal and informal networks (Haakansson and Snehota, 1995). Finally, several studies have attempted to measure the extent of innovation by 'lead' users in specific sectors or product areas using detailed ad-hoc survey data. Urban and von Hippel (1988), for example, found that 24.3% of a sample of 136 users of printed circuit design software either modified or designed their own software. Similarly, Morrison et al. (2000) showed that 26% of libraries using OPAC (a software based library search system) had either customized or designed their own search systems. In a study related to surgical equipment in Germany, 22% of the surgeons in the sample declared that they had intervened to modify or develop their own versions of the equipment (Lüthje, 2004). In their study of Dutch 'high-tech' firms De Jong and von Hippel (2009) concluded that process innovations were common practice among user firms.

These various streams of research have shown that user firms may contribute to innovation in a variety of ways. 'Active' users may simply provide knowledge and feedback to producers (Eurostat, 2004) while 'lead' users (von Hippel, 1986; Gault and von Hippel, 2009) will innovate on their own in order to develop solutions for their specific needs before the bulk of the marketplace even recognizes the same need. 'Experimental' users (Malerba et al., 2007) are willing to try emerging technologies and attribute intrinsic merit to a product simply because it embodies a new technology. 'User entrepreneurs' go further to take responsibility for the production and commercialization of products/services that they have first developed for their own use (Hienerth, 2006; Shah and Tripsas, 2007). 'Vertically integrated' user firms design and produce components for their in-house use and often sell their component solutions to the open market as well.

While these studies provide useful insights into the various kinds of contributions that demand and, more specifically, user firms make to the innovation process across industries and product categories, they do not assess the quantitative relevance of innovation by demand with respect to other actors. Moreover, it is not clear if and how the contribution of demand changes over time. Our objective in this article, therefore, is to examine the magnitude of innovation by demand from the perspective of a sectoral system in which different actors, with different competencies, knowledge bases, objectives, organizational structures, and behaviors, may be involved in innovation. By doing so, this study aims to shed light on some of the questions that previous studies have left unanswered. Within a sectoral system, what extent of total innovations is developed by demand? What differences exist across various types and categories of demand? Does the magnitude of innovation by demand change over time?

Our research focuses on one sector, semiconductors. We define demand in this sector as firms that mainly use semiconductor technology and semiconductor chips in either their products or their production processes. In this study, therefore, demand is synonymous with intermediate users or user firms and innovation by

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