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What prevents spillovers from the pool of knowledge?

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Abstract

This paper surveys theoretical and empirical literature on non-pecuniary flow of knowledge and the conditions and limitations for firms to benefit from positive externalities. Spillovers from the pool of accumulated knowledge generated by technological and scientific development is considered to be a key factor for economic development in modern growth models. Knowledge spillovers has also been a major topic of empirical research on firms' innovation and economic performance over the last thirty years or more. By exploiting theoretical and methodological advances, and using more comprehensive, complex and detailed data sources, scholars from various scientific disciplines have improved the identification of factors, mechanisms, and channels that influence flows of knowledge within and across industries, technological regimes and regions. This research has deepened the understanding of the economic importance of knowledge spillovers.

Keywords: externalities; innovation; knowledge spillover; productivity; technology

JEL codes: L20; M13; O31; O33; O40

1 Introduction

There are very large differences in productivity across countries. The richest countries produce over 30 times more output per worker than the poorest countries. Even within the rich countries, we observe considerable differences in output per workers. These differences can be found within sub-industries and industries as well as between the various industries of an economy. Studies across countries show that the 10 top percentile of the productivity distribution in a sub-industry produce more than twice as much output with the same measured inputs as the 10 bottom percentile plants – even among similar enterprises (Syverson, 2004; Foster, Haltiwanger and Syverson, 2008; Gibbons and Henderson, 2012). These differences are found to be rather persistent over time (Henderson, 2021).

An extensive empirical literature has found that differences in innovation intensity are a crucial factor for differences in productivity. See for example Hall, Lotti and Mairesse (2009) for Italy, Arvanitis, Sydow and Woerter (2008) for Switzerland, Mairesse, Mohnen and Kremp (2005) for France, Masso and Vahter (2008) for Estonia, Gu* and Tang (2004) for Canada, Baum, Lööf, Nabavi and Stephan (2017) for Sweden, and Morris (2018) considering harmonized and comparable data on a total of 40,577 small, medium, and large mainly non-OECD firms surveyed in the World Bank Enterprise Surveys (WBES).

The literature of technological change often distinguishes among different types of innovations. A first common distinction is between process and production innovations. A second distinction is between radical (macro) and incremental innovation (micro). Most innovations are incremental product inno-

vations making improvements or expanding the variety of existing goods and services.

Understanding the sources of innovation has been a central concern of researchers from different research areas studying why some companies perform better than others. Schumpeter raised the questions whether large incumbent firms were likely to be more innovative than smaller ones, or whether new entrepreneurial entrants were the key drivers of innovation. Later, Romer (1986) introduced spillovers from the pool of accumulated knowledge generated by technological and scientific development as a key factor for sustained innovation end economic development in the endogenous growth model. This theeoretical view is supported by a large body of empirical work showing that the social return of R&D investments is significantly higher than the private return, and that this gap can be largely attributed to spillovers from the pool of knowledge. (Griliches, 1992).

The impact of spillovers for economic development was first pointed out by Marshall (1890), who argued that concentration of businesses of a similar character in particular localities give rise to beneficial externalities through free interchange of ideas. Since then, scholars from various scientific disciplines have tried to identify factors, mechanisms, and channels that influence flows of knowledge within and across industries, technological regimes, and regions.

Spillovers may occur in many different ways. With an allusion to the production chain, the literature distinguishes between upstream and downstream flows (and sometimes midstream flows). Upstream flow refers to spillovers from sources needed to gather the inputs required to create a product, while downstream flow concerns spillovers from direct contacts with customers in

the sales stage. The flow of knowledge can move in both directions along this metaphorical river.

The spillover process also has a vertical and a horizontal dimension. From the "creative destruction" point of view, emphasized by Schumpeter and theoretically formalized in endogenous growth models, spillovers are associated with vertical innovation and technical progress on a given array of products with the potential to make existing goods, and sometimes entire industries, obsolete. Horizontal spillover is usually associated with imitation or incremental innovations rather than radical innovations. The two approaches are natural complements to each other and have been found to be powerful analytical tools for addressing a wide range of questions. This applies to a large extent to studies in international economics where knowledge spillovers through trade (mainly imports, but also exports) and foreign direct investments (FDI) have been examined extensively for a long period of time. By distinguishing between spillovers within or between sectors, recent research has been able to identify more clearly the technological and economic significance of knowledge spillovers between companies in different countries. See for instance Smarzynska Javorcik (2004).

Proximity is a central aspect of the extensive spillover literature. Most of this research is based on geographical, technological, and industrial proximity, but to some extent also social proximity. With a rough generalization of the literature, it is possible to draw two overall conclusions from it. Firstly, the improved communication technology implies that the importance of proximity has been reduced in some areas, but remains in others (regarding FDI and trade, see (Keller, 2010)]. Secondly, better analytical methods of addressing endogene-

ity and spatial relations have resulted in increased precision of the assessments of spillover effects and have produced somewhat smaller coefficient estimates for both distance and borders (Autant-Bernard and LeSage, 2011).

While the public pool of knowledge accumulates with the regular supply of knowledge from a large amount of marginal contributions and a much smaller number of radical innovations, a few major breakthrough technologies play a crucial role in the long-term creation of knowledge. These general purpose technologies (GPTs) are defined by the fact that they have a technology that initially has much scope for improvement and eventually comes to be widely used. They have many uses and many technological complementarities before their potential finally ceases. An early wave of technologies that met these criteria were water power, textiles, and iron. Their development from rise to peak and decline (measured by patents) lasted for more than half a century starting from the mid-1780s. The most significant GPTs of our time are found in areas such as digital networks, software, and new media with breakthroughs dating to the late 1980s and a possible peak already after 20-30 years. A GPT enables dramatic economic changes by stimulating new applications in downstream sectors, creating new industries, rejuvenating existing sectors, and providing necessary conditions for both new radical innovations and complementary innovations that benefit households, firms, and the overall economy (Bresnahan and Trajtenberg, 1995; Jovanovic and Rousseau, 2005; Bresnahan, 2010). These crucial processes for industrial dynamism and sustainable growth of economy and welfare could not happen without a widespread non-pecuniary dissemination of ideas from the public pool of knowledge.

The rest of this section surveys the literature that examines determinants

which complicate or facilitate a company's opportunities to benefit from the accumulated pool of technological and other economically valuable knowledge, and is organized in the following way. Section II discusses the nature of technological knowledge, knowledge flows, spillovers, and externalities. Here, we will look, on the one hand, at the public good nature of technological knowledge (non-rivalness and non-excludability), and, on the other hand, at the protection methods that hinder the flow of knowledge across firms. Section III discusses two lines of theories on knowledge spillovers. The first concerns firms' external milieus and the second analyses the kind of relationship between the originator and the receiver of knowledge. Section IV discusses empirical studies.

2 Technological knowledge, spillovers, and externalities

While science may be characterized as generic set of results usable in a wide range of industries, technology is commonly likened to a recipe in a cookbook. The total amount of technological knowledge in a society comprises a pool of opportunities to be translated into new innovations, products, and processes.

A major assumption of the Solow growth model (i.e., the neoclassical growth model) is that technology is free. This means that it is publicly available as a *non-excludable, non-rival* good. Technology seems to be a valid candidate to be considered a public good (Acemoglu, 2009). Once the society attains useful knowledge for increasing the efficiency of production, this knowledge can be applied by any firm without others impinging on the use of it. The endoge-

nous growth theory nuances this assumption to *largely non-rival* and *partly non-excludable*, which implies that a firm discovering a new technology may use patent or trade secrecy to temporarily prevent others from using it.

Knowledge generated outside the firm may be accessed by a firm in many different ways. Scholars make a distinction between knowledge transfer and knowledge spillover. Critical to the concept of knowledge transfer is a market-like compensation of the value of knowledge disseminating between involved parties. The term *knowledge spillover* relates to flows that are not or under-compensated.

Due to involuntary leakage and externalities, R&D investing companies may not appropriate the full return on their efforts. The wedge between private and social return on R&D is considered as a market failure (Arrow, 1962) resulting in underinvestment in R&D without policy interventions. This has come to justify direct government funding and R&D tax incentives to compensate companies for involuntary knowledge leakage, as well as public measures to protect intellectual property rights.

While technological knowledge by its nature is non-rival in use, the question remains – to rephrase Dosi and Nelson (2010) – why not all firms in a particular technological domain adopt the best publicly available technology. The simplest answer is that many firms are not aware of the best technology, and even if they were informed about its existence, they don't have the capabilities to apply it. According to Dosi and Nelson (2010), this might have little to do with the possibility of protecting technology legally by patents or other protection mechanism.

A major message from literature across different research fields and over

time is that in most sectors of the economy technological progress is cumulative in nature, where experiences from current failures and successes are transformed into tomorrow's learning routines and knowledge stock. Because technological knowledge is partly tacit ("we know more than we can tell", Polanyi (1966)) and often embedded in routines and complex organizational practices (Liang, Wang, Xue and Ge, 2017), it doesn't flow to all firms even within the same technology area, region, or ownership group. Similar to science, technology's intrinsic indivisibility means that "the value of a half glass is less than half of the full glass". This implicates that it requires absorptive capacity from 'learning by doing' and 'learning by using'to tap from the pool of knowledge.

3 Theoretical views on knowledge spillovers

Knowledge spillovers play an important role in many models of economic development. In the original formulation of endogenous technological change by (Romer, 1986, 1990), there cannot be endogenous growth without knowledge spillovers from past R&D. More recent views on spillover includes a broader aspect of economically valuable knowledge than only R&D.

3.1 Diversification and specialization

An extensive body of research has investigated whether local firms or local industry may benefit most from spillovers as externalities related to urbanization and specialization economies and how they influence innovations through geographical or technological proximity.

Jane Jacobs (Jacobs, 1969) and the Marshall–Arrow–Romer (MAR) model provide two diverging theoretical views on conditions for spillovers. Jacobs suggests the importance of diversity and argues that the most important source of knowledge spillovers is external to the industry in which the firm operates. Since the intensity and diversity of complementary knowledge across diverse firms and economic agents is greatest in cities, they will act as an engine of economic growth by facilitating the exchange of ideas among workers and entrepreneurs.

By contrast, the MAR spillover model suggests that an increased concentration of a particular industry within a specific geographic region creates the best conditions for knowledge spillovers. The closer the firms geographically are to one another within a common industry, the greater the MAR spillover. Workers and firms within the same industry are engaged in similar innovation and production activities, which lowers costs and increases transaction in communication resulting in a higher probability of knowledge spilling.

A different literature has emphasized the impact of networks and social capital found within a geographic region (Agrawal, Cockburn and McHale, 2003). This literature covers key aspects of both the MAR and Jacobs views on spillovers. Relational networks exist at multiple levels of analysis because they can link individuals, groups, firms, industries, geographic regions, and nation-states. In addition, they can tie members of any one of these categories to members of another category (Audretsch and Feldman, 2004).

3.2 Relationships between the originator and receiver

The concepts of concentrated and diversified knowledge are closely linked to the idea of absorptive capacity, which is firms ability to recognize, assimilate, and apply new technology (Cohen and Levinthal, 1989, 1990). Firms engaged in their own R&D are supposed to develop internal capacity to acquire and benefit from external knowledge.

The capacity and potential for profit-maximizing firms to build new knowledge using external ideas have been studied in comprehensive innovation literature, to a significant extent with references back to "Schumpeter MARK I" (1911) and "Schumpeter Mark II" (1942). In the first view, innovations are mainly carried out by new entrants with a relatively low level of accumulated knowledge. In the latter, knowledge is mainly generated in large corporations, while new firms may enlarge the existing knowledge base through spillovers (Schumpeter, 2017, 2010). The famous term "creative destruction" refers to what may happen to incumbent firms in industries where technological advance is rapid and they are unable to seize novel opportunities associated with new technological paradigms (Dosi and Nelson, 2010).

Rather than distinguishing between the MARK-regimes, a recent theoretical framework called "Knowledge Spillover Theory of Entrepreneurship" (KSTE) combines the two and hypothesizes that new firms may enlarge the existing knowledge base if they are able to tap the stock of knowledge through spillovers, absorptive capacity, and knowledge combination (Audretsch, Keilbach and Lehmann, 2006; Audretsch, Colombelli, Grilli, Minola and Rasmussen, 2020).

While Arrow (1962) emphasized the aspect of underinvestment regarding

knowledge spillover, recent theoretical development also allows for beneficial effects of spillover for the originating firm. Relying on (Cohen and Levinthal, 1990), this theory states that investments in knowledge enable the organization to be a better recipient of knowledge generated by other firms because of a greater absorptive capacity.

In accordance with Weitzman (1998) and the recombinant knowledge approach, Agarwal, Audretsch and Sarkar (2007) suggest that spillovers may result in a win-win situation if one considers multiple time periods. This occurs because the knowledge creator and recipient might change roles, or because spillovers result in a wider ecosystem that complements the focal firm's offer. Based on this core thesis, they propose the concept of creative construction as an alternate view to the notion of creative destruction.

Consistent with the creative construction concept, Yang, Phelps and Steensma (2010) discuss innovation in terms of recombination of existing knowledge or reconfiguration of the ways in which knowledge elements are linked. Assuming that this knowledge has been received from a spillover process, it can provide some benefit to the original creator as spillins, thereby enhancing its stock of knowledge. For instance, a spillover process from an incumbent innovator to a start-up firm through directors linked to both firms may create opportunities for recombination. In a reverse flow, the linked directors return information from the innovating start-up to the originating firm, adding to its knowledge pool in a continued recombination process (Antonelli, Krafft and Quatraro, 2010; Saviotti, 2007).

In a longitudinal study of 87 telecommunications manufacturers, Yang et al. (2010) found that a firm's rate of innovation and the extent to which these in-

novations benefit from the spillover knowledge pool are greater when this pool is larger in size and similar to the firm's knowledge base. Thus, an originator's spillover knowledge pool represents all external knowledge components that have been linked directly to its knowledge by recipient firms through spillover.

Building on the idea that spillovers should be considered a wider ecosystem complementing and cross-fertilizing existing ideas, the *Knowledge spillover view of strategic entrepreneurship* (Agarwal, Audretsch and Sarkar, 2010) describes a bidirectional dissemination with feedback processes between the original knowledge creators and the recipients. Through a mutual process of spillovers and spillins, the originator's stock of knowledge may enhance.

A basic assumption in the more recent theoretical views on spillover is that the spilling firm generates a firm-specific knowledge pool that may influence its innovativeness positively through novel combinations of knowledge by recipient firms. These novel combinations represent templates, which can be learned vicariously and incorporated into the originating firm's knowledge base. Because the spillover knowledge pool is the direct extension of the originating firm's knowledge, it can more easily understand and exploit knowledge in the common pool.

4 Empirical work on spillovers

The importance of spillovers from the social, industrial, technological, geographical, or firm-specific pool of knowledge has been a major topic of empirical research over the last thirty years or more (Bloom, Schankerman and Van Reenen, 2013). A central issue in the literature is how firms are affected

positively by knowledge spillovers and negatively through the stealing of business from product market rivals. See for instance (Cassiman and Veugelers, 2002, 2006).

Another main theme is to examine the specific channels through which knowledge dissemination takes place. A substantial body of work on patents and patent citations backwards and forwards tries to track knowledge spillover and its impact on R&D, innovations, and growth (Hall, Jaffe and Trajtenberg, 2005; Jaffe, 1986; Jaffe, Trajtenberg and Henderson, 1993; Jaffe and De Rassenfosse, 2019; Trajtenberg, 1990).

In concordance with the Schumpeterian view that incumbent organizations represent the origin of innovation opportunities, the empirical literature on start-ups and other small businesses has linked successful performance to knowledge and experience from incumbent firms or organizations. This strand of research includes firm and university spin-offs Agarwal, Echambadi, Franco and Sarkar (2004); Audretsch and Feldman (1996); Bercovitz and Feldman (2006); Colombelli, Grilli, Minola and Mrkajic (2019); Klepper (2001); Klepper and Sleeper (2005), start-up firms linked to their parents Acs, Audretsch and Lehmann (2013); Eckhardt and Shane (2003); Klepper and Sleeper (2005); Klepper (2010); Koellinger (2008), as well as geographical and industrial clusters, relational networks, innovation systems, and value chains (Breschi and Malerba, 2001; Feldman, 1994; Fritsch and Franke, 2004; Klepper, 2010; Rodríguez-Pose and Crescenzi, 2008).

The recombinant knowledge model (Weitzman, 1998) offers a complementary approach for micro-oriented studies of spillovers between incumbent organizations and new entrants. Recombinant innovation may be the result of ongoing research by the incumbent and complementary ideas on the same knowl-

edge base by the start-up firm (Colombelli, Krafft and Vivarelli, 2016). It should be noted that innovative incumbents' returns on research depends on the balance between benefits from their use of innovations and the possible costs of spillovers. If spillovers flow to rivals, they may reduce the incumbents' returns from research efforts. However, strategic complementarity in innovation triggers the opposite effect, and increases the rate of return (Bloom, Schankerman and Van Reenen, 2013; Arora, Belenzon and Sheer, 2021). Within this research area, and using a patent citation approach for tracking spillovers, Fleming and Sorenson (2001) find that too much interdependence as well as too little interdependence reduces the likelihood for a successful spillover process. Focusing specifically on information and communication technologies (ICTs), Antonelli, Krafft and Quatraro (2010) show that the recombination processes are more effective when they are characterized by higher levels of coherence and specialization of the knowledge space.

While spillovers can erode or destroy technological competencies for the firm investing in R&D, recent studies suggest that board interlocks with other firms and possible leakages of knowledge may encourage the competitive advantage of the focal firm through inter-firm collaboration (Slater, Mohr and Sengupta, 2014; Chandy and Tellis, 2000). Given the proven significance of interlocks as conduits for knowledge spillovers among firms, recent research investigates the importance of these links specifically for innovative firms. Within this literature, Li (2019) find that interlocks with R&D-intensive firms are more important for technological exploration than board links to other categories of firms. The educational background of the directors is another factor that may influence the efficiency of an interlocked board. Higher levels of education

among board directors has been found to increase their willingness to use external information, develop networks, make use of consultants, or develop more detailed accounting and monitoring in large firms (Lybaert, 1998; Bennett and Robson, 2004).

Recently, some innovation studies were able to deepen the analysis on the board of directors in its role as channel for spillovers, by using more detailed data, and in some cases employing improved identification strategies to enable a causal interpretation of results. Among these papers, Balsmeier, Buchwald and Stiebale (2014) analyze panel data on the largest public German companies, while Balsmeier, Fleming and Manso (2017) study major public US-based firms, and Robeson and O'Connor (2013) examine Fortune 1000 firms. Helmers, Patnam and Rau (2017) use data on all publicly listed firms in India, Srinivasan, Wuyts and Mallapragada (2018) apply their analysis on publicly listed U.S. firms for consumer packaged goods, and Arzubiaga, Kotlar, De Massis, Maseda and Iturralde (2018) study family businesses. Despite using different measures of innovation, of board members' competence, of channels for external networks, and of knowledge in the external networks, and regardless of employing different econometric approaches, all the studies above come to a similar conclusion: the board of directors can be an important link for transferring knowledge to innovative companies. Baum, Lööf, Stephan and Viklund-Ros (2022) find that this conclusion also holds for start-ups with their specific characteristics due to their lack of experience that distinguishes them from established and larger firms.

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