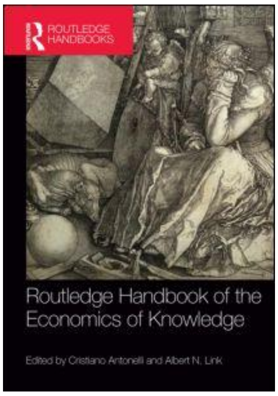

Routledge Handbook of the Economics of Knowledge

Cristiano Antonelli, Albert N. Link

From knowledge to innovation

Publication details
https://www.routledgehandbooks.com/doi/10.4324/9780203082324.ch3
David B. Audretsch, Lehmann Erik E., Joshua Hinger
Published online on: 08 Dec 2014

3

From knowledge to innovation

The role of knowledge spillover entrepreneurship

David B. Audretsch, Erik E. Lehmann, and Joshua Hinger

1. Introduction

Knowledge is generally considered to be the essential ingredient for innovative activity. However, knowledge is not equivalent to innovation. The purpose of this chapter is to explain the role of entrepreneurship in facilitating the spillover of knowledge from an organization where that knowledge is created to a new organization where it is used for innovative activity. The body of the chapter is organized in three primary sections. The first section discusses the knowledge production and the emergence of the knowledge production function, which was primarily cited in the academic literature between 1983 and 1997. Additionally, this section highlights the model's strengths and weaknesses in regards to various levels of analysis, as well as the three stages of the innovation process and its variable measurement constraints. The second section then discusses knowledge spillover theory, the distinctions between information and knowledge, and highlights how the impacts of knowledge spillover can be estimated within the framework of the knowledge production function. The third section discusses the theoretical links between entrepreneurial activity and knowledge spillover, and how these links assist in explaining the heterogeneity that is observed among different levels of analysis.

2. Knowledge production

Along with the emergence of the Endogenous Growth Theory in the mid-1980s (see Romer, 1986, 1990), interest in innovative activity began to increase, and the literature responded by fitting the innovative process into the well-known production function model (Solow, 1956). The production function model in economics connects inputs in the production process to outputs. As Milton Friedman (1975) famously quipped, "There is no such thing as a free lunch," implying that inputs in the production process are a requisite to producing outputs. Ample theoretical models and evidence providing empirical validation of the production function model exist in the economics literature.

Consequently, as the focus on innovation as an output began to emerge in the economic literature, one prevalent approach was to embed innovation into the more general production function model. As for production, the unit of analysis is typically at the firm level, while levels of innovation are examined as the output. The inputs are generally considered to be knowledge, or some proxy measurement of knowledge-related input, such as research and development, human capital, or academic research (see Audretsch, Keilbach, and Lehmann, 2006).

The theoretical specification Griliches (1990) termed the *knowledge production function* typically specifies knowledge inputs as exogenous to the model and influencing the dependent variable – innovative activity. The empirical estimation of the knowledge production function has been influenced by measurement problems. Both the independent variables and dependent variables that are used to estimate the knowledge production function are not easily measured. Concepts such as knowledge and innovative activity do not lend themselves to obvious quantification. Paul Krugman (2013) commented in reference to the decline of the New Growth Theory, "too much of it involved making assumptions about how unmeasurable things affected other unmeasurable things." Similarly, the empirical literature on estimating the knowledge production function has been limited in its ability to measure both the knowledge inputs as well as the innovative outputs.

Attempts to measure innovative activity have revolved around three stages of the innovative process. The first stage involves production inputs. Measures of inputs into the innovative process, such as research and development (R&D) expenditures, or the share of employment devoted to research and development, have been used as proxy measurements for innovative activity. A clear limitation of using R&D activity as a proxy measurement for technological change is that R&D reflects only the resources devoted to producing innovative output, but not the amount of innovative activity actually realized. That is, R&D is an input in the innovation process, not an output. As Mansfield (1984) points out, not all efforts within a formal R&D laboratory are directed towards generating innovative output in any case. Rather, other types of output, such as imitation and technology transfer, are also common goals in R&D laboratories.

The second stage involves an intermediate output, which exceeds that of a pure input in the production process, but has not yet reached the level of final output. The most prevalent measure of an intermediate output is the number of inventions with patents. In fact, inventions granted patent protection seem to be the most common measure used as a proxy for innovative activity. Scholars have typically interpreted this new measure not only as being superior to R&D but also as representing a *bona fide* measure of innovative output. However, it should be emphasized that inventions that have received legal patent protection are not, in fact, a direct measure of innovative output, but rather they reflect an intermediate stage of the innovation process. While the granting of a patent for an invention does reflect that a certain level of new technical knowledge has been attained, there is absolutely no guarantee that new technical knowledge has a positive economic value, other than the fact that someone is willing to incur the cost of obtaining that patent. While innovations and inventions are related, they are not identical.

Therefore, many inventions that are granted a patent do not necessarily generate innovative activity, in that they do not result in an innovation, or a positive revenue stream. Although this is not to suggest that innovations are mutually exclusive with positive revenue streams. Additionally, several valuable and historically significant innovations stemmed from inventions that were never patented. Benjamin Franklin, one of history's most notable inventors, did not patent his innovations, such as the lightening rod, the Franklin stove, the odometer, or bifocal glasses. He stated "As we benefit from the inventions of others, we should be glad to share our own … freely and gladly" (Lobel, 2013, p. 121).

The rather striking gaps between patented inventions on the one hand and realized innovations on the other led Scherer (1983) to observe that the "propensity to patent" is not constant across specific technologies, firms, or industries. Rather, just as certain firms, technologies, and industries have a greater propensity to patent inventions, others exhibit a lower propensity to patent inventions. Similarly, the propensity of those patented inventions to result in innovations also varies systematically across technologies, firms, and industries. As Scherer (1983, pp. 107–108) explains,

> The quantity and quality of industry patenting may depend upon chance, how readily a technology lends itself to patent protection, and business decision-makers' varying perceptions of how much advantage they will derive from patent rights. Not much of a systematic nature is known about these phenomena, which can be characterized as differences in the propensity to patent.

A similar view about the reliability of patents as a measure of innovative activity is expressed by Mansfield (1984, p. 462),

> The value and cost of individual patents vary enormously within and across industries … Many inventions are not patented. And in some industries, such as electronics, there is considerable speculation that the current patent system is being bypassed to a greater extent than in the past. Some types of technologies are more likely to be patented than others.

The varying propensities to patent across technologies, industries, and firms indicate that inferences about innovative activity based on patent data are inherently erroneous. As Pakes and Griliches (1980, p. 378) conclude, "patents are a flawed measure [of innovative output]; particularly since not all new innovations are patented and since patents differ greatly in their economic impact." Similarly, Griliches (1990, p. 1669) poses the question, "Patents as indicators of what?" To which he answers:

> Ideally, we might hope that patent statistics would provide a measure of the [innovative] output … The reality, however, is very far from it. The dream of getting hold of an output indicator of inventive activity is one of the strong motivating forces for economic research in this area.

While the first two stages attempting to measure innovative activity involve measures of inputs and intermediate outputs, the third stage provides direct measures of innovative activity. Direct measures of innovative activity have ranged from new products and processes introduced into the market, to the share of sales accounted for by new products. Such direct measures attempt to identify new products and processes introduced into the market, and therefore enable the observation of innovative outputs, not just production inputs.

The knowledge production function has been found to hold most strongly at broader levels of aggregation. The most innovative countries are those with the greatest investments to R&D. Little innovative output is associated with less developed countries, which are characterized by a paucity of new economic knowledge production. Similarly, the most innovative industries also tend to be characterized by considerable investments in R&D and new economic knowledge. Not only are industries such as computers, pharmaceuticals, and instruments high in R&D inputs that generate new economic knowledge, but also in terms of innovative outputs (Audretsch, 1995). By contrast, industries with little need for R&D, such as wood products, textiles, and paper, also tend to produce lower amounts of innovative output. Therefore, the knowledge production model linking knowledge-generating inputs to innovative outputs certainly holds at the more aggregated levels of economic activity.

The relationship between knowledge-generating inputs and outputs becomes less compelling at the disaggregated microeconomic level of the enterprise, establishment, or even line-of-business. For example, while Acs and Audretsch (1990) found that the simple correlation between R&D inputs and innovative output was 0.84 for four-digit standard industrial classification (SIC) manufacturing industries in the United States, it was less than half, 0.40, among the largest U.S. corporations. The knowledge production function model becomes even less compelling in view of the recent wave of studies revealing that small enterprises serve as the engine of innovative activity in certain industries. These results are startling, because as Scherer (1991) observes, the bulk of industrial R&D is undertaken in the largest corporations; small enterprises account only for a minor share of R&D inputs.

3. Knowledge spillovers

Kenneth Arrow's classic 1962 article remains one of the most cited in the field of economics because he explained that information is inherently characterized as a public good in some cases, and by positive externalities in other cases. This is because multiple economic agents are able to reuse information. For example, opportunistic entrepreneurs are able to use information that has been previously utilized by a firm, organization, or individual, in order to produce additional value that was otherwise unrealized in the market. Much of the ensuing literature responding to Arrow's insights, at least from the perspective of the firm, was based on concerns for the under-investment in the creation of information, because the ability to fully accrue the returns from such investments is limited. As Charles Ferguson (1988, p. 61) argues,

> Fragmentation, instability, and entrepreneurialism are not signs of well-being. In fact, they are symptoms of the larger structural problems that afflict U.S. industry. In semiconductors, a combination of personnel mobility, ineffective property protection, risk aversion in large companies, and tax subsidies for the formation of new companies contribute to a fragmented "chronically entrepreneurial" industry. U.S. semiconductor companies are unable to sustain the large, long-term investments required for continued U.S. competitiveness.

Companies avoid long-term R&D, personnel training, and long-term cooperative relationships because these are presumed, often correctly, to yield no benefit to the original investors. Economies of scale are not sufficiently developed. An elaborate infrastructure of small subcontractors has arisen in Silicon Valley. Personnel turnover in the American merchant semiconductor industry has risen to 20 percent compared with less than 5 percent in IBM and Japanese corporations. Fragmentation discouraged necessary coordinated action – to develop technology and also to demand improved government support.

However, Arrow's characterization of information became increasingly re-characterized as knowledge. The main distinction between information and knowledge involves three fundamental characteristics. The first is the extent of uncertainty. Information is relatively certain and based on fact. By contrast, knowledge is inherently uncertainty. While the economic value of information is relatively certain, the economic value of knowledge is uncertain.

The second characteristic distinguishing knowledge from information is its high degree of asymmetry across economic agents. This means that the economic valuation of knowledge assigned by any particular agent differs significantly from the assigned economic valuation of that same knowledge by a different economic agent. Not only is the outcome, or economic value of knowledge, uncertain but the expected value of that knowledge differs significantly across economic agents. This is a contrast to information, which is not only associated with less uncertainty but also by a low degree of asymmetries across economic agents. Thus, the economic valuation of information tends to be relatively homogeneous while the economic valuation of knowledge is heterogeneous.

The third characteristic involves the cost of transacting information versus knowledge across economic agents. While the cost of transacting information across economic agents is trivial, especially in the internet-era, the cost of transacting knowledge is not trivial. Information consists largely of codified facts, but knowledge has a considerably greater component of tacit understanding. To transact tacit knowledge is costly and typically requires face-to-face communication. Due to the importance of face-to-face communication in transacting knowledge, the geographic range of such knowledge spillovers plays an important role.

A rich and growing literature has found compelling empirical evidence confirming that knowledge investments create significant externalities in that they contribute to the innovative activity of other firms (Audretsch and Feldman, 1996; Jaffe, 1989; Audretsch and Stephan, 1996; Anselin, Varga, and Acs, 1997, 2000; Acs, Anselin, and Varga, 2002; Acs *et al*., 2009, 2012; Braunerhjelm *et al.* 2010; and Jaffe, Trajtenberg, and Henderson, 1993). An important finding of this literature is that knowledge spillovers tend to be geographically concentrated within close spatial proximity to the knowledge source. Studies show that while knowledge has a high propensity to spill over, such knowledge spillovers are geographically bounded (Audretsch and Lehmann, 2005; Audretsch and Keilbach, 2007).

Krugman (1991, p. 53) expressed skepticism that knowledge spillovers could actually be measured and analyzed, because, "knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked." However, the ensuing studies, in many ways responding to Krugman's implied challenge, have argued otherwise. For example, Jaffe, Trajtenberg and Henderson (1993, p. 578) conclude that, "knowledge flows do sometimes leave a paper trail, in the form of citations in patents."

One prevalent approach to estimate the impact and extent of knowledge spillovers is based on the knowledge production function. According to Jaffe (1989), knowledge spillovers can be modeled within the context and framework of the knowledge production function:

$$I_{si} = IRD^{\beta_1} * UR_{si}^{\beta_2} * \left(UR_{si} * GC_{si}^{\beta_3}\right) * \varepsilon_{si} \tag{1}$$

where *I* refers to the output of innovative activity, *IRD* represents R&D investment by private companies and organizations, *UR* reflects investments by universities on the research expenditures undertaken at universities, and *GC* measures the geographic coincidence of university and corporate research. The unit of observation for estimation was at the spatial level, *s*, a state, and industry level, *i*. Estimation of equation (1) essentially shifted the knowledge production function from the unit of observation of a firm to that of a geographic unit.

Implicitly contained within the knowledge production function model is the assumption that innovative activity should take place in those regions, *s*, where the direct knowledge-generating inputs are the greatest, and where knowledge spillovers are the most prevalent. Audretsch and Feldman (1996), Anselin, Varga, and Acs (1997, 2000), and Audretsch and Stephan (1996) link the propensity for innovative activity to cluster together to industry specific characteristics, most notably the relative importance of knowledge spillovers.

4. Knowledge spillover entrepreneurship

More recently, a different approach has suggested that there may be alternative perspectives shedding a different light, not just on why some people choose to become entrepreneurs while others do not, but also how and why entrepreneurship is a critical issue in regards to improving economic performance (see Acs and Audretsch, 2010; in particular Alvarez, Barney, and Young, 2010). According to the knowledge spillover theory of entrepreneurship, the context in which decision-making is derived can influence one's determination to become an entrepreneur. In particular, a context that is rich in knowledge generates entrepreneurial opportunities from those ideas created but not commercialized by incumbent organizations. By commercializing those ideas, which evolved from an incumbent organization but commercialized with the creation of a new firm, the entrepreneurs not only serve as a conduit for the spillover of knowledge, but also for the ensuing innovative activity and enhanced economic performance (Audretsch and Lehmann, 2005; Leyden and Link, 2013).

The knowledge spillover theory of entrepreneurship brings together contemporary theories and thoughts of entrepreneurship with prevailing theories of economic growth (see Acs, Audretsch, and Lehmann, 2013). In particular, this approach advances the microeconomic foundation of the endogenous growth theory by providing a new framework explaining the unobserved heterogeneity of growth rates between regions and nations. While keeping constant the primary research question involving intrinsic motivation among entrepreneurs, the knowledge spillover theory is concerned with the contextual variables that shape entrepreneurship. Considering that entrepreneurship and new venture creations are not a recent phenomenon, and by keeping the intrinsic motivations of entrepreneurs constant, the observed increase in the rate of startups and entrepreneurial activities should reflect a change in the benefits and costs of creating a new venture based on changes in the benefits and costs of the operating context. Knowledge created by incumbent firms and research organizations, which is underexploited and not fully commercialized for purposes of economic gain, then spills over to other economic agents – entrepreneurs – and is identified as the primary factor in shifting benefits and costs. To this end, we propose the concept of the *Knowledge Incubator* – a government, university, private firm, or research institution that has, through its own labor and resources, developed new knowledge with potential in the commercial markets but has, for various reasons such as uncertainty or disinterest, instead opted not to commercialize and exploit said knowledge, therefore allowing the knowledge to be spilled over to other willing economic agents. The knowledge incubator is unique specifically due to its decision not to enter the market with its new endogenously developed knowledge.

Economic agents, which are able to absorb knowledge spillovers and convert them into economic knowledge, are not required to bear the full costs of the knowledge development. This specific type of entrepreneur, one who utilizes knowledge spillovers, and does not bear the full costs of the newly developed knowledge, is referred to as an *opportunistic entrepreneur*. This individual, or group of individuals, is unique from other entrepreneurs in the sense that they are utilizing the spillover from the knowledge incubator, commercializing this knowledge by founding a new firm, entering the marketplace, and converting the new knowledge into economic knowledge. Consequently, the expected benefits increase via exploitation of the knowledge spillovers, which is ideally converted into economic knowledge and ultimately fosters economic growth.

Knowledge spillover theory of entrepreneurship contributes to the existing body of knowledge by explaining how and why knowledge spills over, and in what manner entrepreneurship acts as the mechanism by which knowledge evolves into economic knowledge within a given framework. While new ventures in the tech-sectors have led to the well-known erosion of previously existing industries (Schumpeter, 1934), such as Facebook, technological change and progress have been considered drivers of economic growth since the first industrial revolution. Since then, new venture creation and technological change were considered to be almost entirely exogenous. The most influential factors in the last few decades can be characterized by a shift in

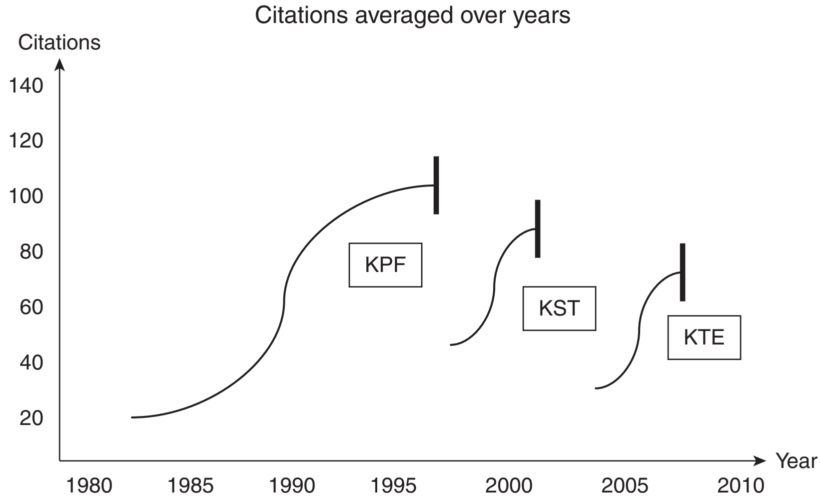

Figure 3.1 Emergence and diffusion of the knowledge spillover theory of entrepreneurship

the benefits and costs of the contextual factors, which have led to innovations and new venture creation far beyond exogenous factors. Not only innovations, but new ventures and entrepreneurial firms also often fall like manna from heaven.

The knowledge spillover theory of entrepreneurship thus shifts the unit of analysis away from firms and knowledge endowments assumed to be exogenous, and focuses attention on individual agents, specifically *opportunistic entrepreneurs*, who possess new knowledge endowments characterized as knowledge that has been captured from spillovers. This suggests a strong relationship between knowledge spillovers on the one end of the spectrum, and entrepreneurial activities on the other, while both have influence on the growth rates of regions and countries. Unobserved heterogeneity between regions and countries is based on differences in the knowledge spillover endowment and the ability to foster entrepreneurship (entrepreneurship capital), or in other words, unobserved heterogeneity in growth rates is due to differences in the benefits and costs of the knowledge endowments.

Figure 3.1 depicts the evolution of studies analyzing the knowledge production function, knowledge spillovers, and the knowledge spillover theory of entrepreneurship. The number of citations for each literature is measured on the vertical axis, against the year on the horizontal axis. There are two important and observable trends from Figure 3.1. The first is the temporal sequencing of these three strands of literature. The literature on the knowledge production function developed first. The literature on knowledge spillovers developed subsequently. The strand of literature focusing on the knowledge spillover theory of entrepreneurship is in its incipiency.

The second notable observation from Figure 3.1 is that the strands of literature on the knowledge production function and knowledge spillovers have peaked and are producing diminishing returns. By contrast, the strand of literature on the knowledge spillover theory of entrepreneurship is still growing.

5. Conclusions

There are both compelling theoretical reasons and empirical evidence suggesting that knowledge is not the equivalent of innovation. Rather, a gap exists between knowledge and innovation.

The knowledge spillover theory of entrepreneurship explains the important role that entrepreneurship plays in spanning this gap. By taking ideas that have been developed in one organizational context and transforming them into innovations in the form of a new firm or organization, entrepreneurship plays an important role in transforming knowledge into innovation.

References

Acs, Z. J. and Audretsch D. B. (1990). *Innovation and Small Firms*. Cambridge, MA: MIT Press.

Acs, Z. J. and Audretsch, D. B. (Eds.). (2010). *Handbook of Entrepreneurship*. New York, NY: Springer.

Acs, Z. J., Anselin, L., and Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, 31(7), 1069–1085.

Acs, Z. J., Audretsch, D. B., and Lehmann, E. E. (2013). The knowledge spillover theory of entrepreneurship, *Small Business Economics*, 41(4), 757–774.

Acs, Z. J., Audretsch, D. B., Braunerhjelm, P., and Carlsson, B. (2009). The knowledge spillover theory of entrepreneurship, *Small Business Economics*, 32(1), 15–30.

Acs, Z. J., Audretsch, D. B., Braunerhjelm, P., and Carlsson, B. (2012). Growth and entrepreneurship. *Small Business Economics*, 39(2), 289–300.

Alvarez, S. A., Barney, J. B., and Young, S. L. (2010). Debates in entrepreneurship: opportunity formation and implications for the field of entrepreneurship. In Z. J. Acs and D. B. Audretsch (Eds.), *Handbook of Entrepreneurship* (pp. 23–46). New York, NY: Springer.

Anselin, L., Varga, A., and Acs, Z. (1997). Local geographic spillovers between university research and high technology innovators. *Journal of Urban Economics*, 42(3), 422–448.

Anselin, L., Varga, A., and Acs, Z. (2000). Geographic and sectoral characteristics of academic knowledge externalities. *Papers in Regional Science*, 79(4), 435–443.

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In R. R. Nelson (ed.), *The Rate and Direction of Inventive Activity* (pp. 609–626). Princeton, NJ: Princeton University Press.

Audretsch, D. B. (1995). Innovation, growth and survival. *International Journal of Industrial Organization*, 13(4), 441–457.

Audretsch, D. B. and Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *American Economic Review*, 86(3), 630–640.

Audretsch, D. B. and Keilbach, M. (2007) The theory of knowledge spillover entrepreneurship. *Journal of Management Studies*, 44(7), 1242–1254.

Audretsch, D. B. and Lehmann, E. E. (2005). Does the knowledge spillover theory of entrepreneurship hold for regions?, *Research Policy*, 34, 1191–1202

Audretsch, D. B., and Stephan, P. E. (1996). Company-scientist locational links: the case of biotechnology. *American Economic Review*, 86(3), 641–652.

Audretsch, D. B., Keilbach, M., and Lehmann, E. (2006). *Entrepreneurship and Economic Growth*. Oxford, UK: Oxford University Press.

Braunerhjelm, P., Acs, Z. J., Audretsch, D. B., and Carlsson, B. (2010). The missing link: knowledge diffusion and entrepreneurship in endogenous growth. *Small Business Economics*, 34(2), 105–125.

Ferguson, Charles H. (1988). From the people who brought you voodoo economics. *Harvard Business Review*, 66(3), 55–62.

Friedman, M. (1975). *There is No Such Thing as a Free Lunch*, La Salle, Il, Open Court, p. iii.

Gerard, A. (1756). *Essay on Genius*, London: W. Strahan.

Griliches, Z. (1990). Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, 18(4), 1661–1707.

Jaffe, A. B. (1989). Real effects of academic research. *American Economic Review*, 79(5), 957–970.

Jaffe A., Trajtenberg, M., and Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, 108(3), 577–598.

Krugman, P. (1991). *Geography and Trade*, Cambridge: MIT Press.

Krugman, P. (2013). The new growth fizzle. *The New York Times*, August 18. Retrieved from http://krugman.blogs.nytimes.com/2013/08/18/the-new-growth-fizzle/?_r=0 (accessed: July 6, 2014).

Leyden, D. P. and Link, A. N. (2013). Knowledge spillovers, collective entrepreneurship, and economic growth: the role of universities, *Small Business Economics*, 41(4), 797–817.

Lobel, O. (2013). *Talent Wants to Be Free*, New Haven, CT: Yale University Press.

Mansfield, E. (1984). Comment on using linked patent and R&D data to measure interindustry technology flows. In Z. Griliches (ed.), *R&D, Patents, and Productivity* (pp. 462–464). Chicago, IL: University of Chicago Press.
Pakes, A. and Griliches, Z. (1980). Patents and R&D at the firm level. *Economic Letters*, 5(4), 377–381.
Romer, P. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, 94(5), 1002–1037.
Romer, P. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5), S71–S102.
Scherer, F. M. (1983). The propensity to patent. *International Journal of Industrial Organization*, 1(1), 107–128.
Scherer, F. M. (1991). Changing perspectives on the firm size problem. In Z. Acs and D. Audretsch (Eds.), *Innovation and Technological Change: An International Comparison* (pp. 24–38). Ann Arbor, MI: University of Michigan Press.
Schumpeter, J. A. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, MA: Harvard University Press.
Solow, R. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, 70(1), 65–94.