# 9 A Survey Review of University Biotechnology and Entrepreneurship Commercialization

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It is a wonder that Columbus discovered America. It would have been an even greater wonder had America never been discovered.

Mark Twain

## 9.1 Introduction

Interest in entrepreneurship as a key force in economics and management has recently exploded, and management and economics scholars have responded with an explosion of academic research. Entrepreneurship may play an even more important role in the science-based knowledge industries driving economic growth and competitiveness in a globalized economy, such as biotechnology. However, the exact role of entrepreneurship in industries such as biotechnology has generally eluded the analytical lens of scholars. As Michael Crichton observes in the opening pages of his epic, *Jurassic Park*, which was memorialized on the screen by Steven Spielberg, "The late twentieth century has witnessed a scientific gold rush of astonishing proportions: the headlong and furious haste to commercialize genetic engineering. This enterprise has proceeded so rapidly – with so little outside commentary – that its dimensions and implications are hardly understood at all."

The purpose of this chapter is to shed some light on the role of entrepreneurship in biotechnology, and in particular, how scientists engaged in biotechnology research at universities become entrepreneurs. By entrepreneurship, we mean in the context of this paper, the process leading to the start-up of a new biotechnology company, which is consistent with the definition posited by Gartner and Carter (2003) in the 2003 edition of the *Handbook of Entrepreneurship Research*, "Entrepreneurial behavior involves the activities of individuals who are

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associated with creating new organizations rather than the activities of individuals who are involved with maintaining or changing the operations of ongoing established organizations.” This definition of entrepreneurship is in contrast to the more general and organization context free definition provided by Sarasvathy, Dew, Velamuri, and Venkataraman, in the 2003 edition of the *Handbook of Entrepreneurship Research*, “An entrepreneurial opportunity consists of a set of ideas, beliefs, and actions that enable the creation of future goods and services in the absence of current markets for them.”

We first link entrepreneurial behavior to scientists and researchers in biotechnology. We then relate scientist commercialization to more general theories and models of entrepreneurial choice. Previous studies analyzing scientist comercialization and entrepreneurship are reviewed in the second section. This literature enables us to infer several main hypotheses predicting scientist entrepreneurship. In particular, by examining why some scientists commercialize their scientific research through entrepreneurship while others do not, this chapter is able to identify that, at least in the case of biotechnology, entrepreneurial opportunities are shaped by the context within which the scientist works as well as the characteristics specific to the scientist. Thus, the evidence suggests that the extent and nature of scientist commercialization in biotechnology are shaped by the particular mode of commercialization pursued by the individual scientist.

## 9.2 Commercialization of Science and Entrepreneurial Choice

Why do some biotechnology scientists choose to commercialize their research and, at least in some cases, do it through entrepreneurship by starting a new biotechnology company? It is a virtual consensus that entrepreneurship revolves around the recognition of opportunities and the pursuit of those opportunities (Shane and Eckhardt 2003). Much of the more contemporary thinking about entrepreneurship has focused on the cognitive process by which individuals reach the decision to start a new firm. But where do entrepreneurial opportunities come from? This question has been at the heart of the entrepreneurship literature and holds for scientists and researchers in biotechnology as well as more generally. On the one hand is the view associated with Kirzner that entrepreneurial opportunities are actually exogenous or independent from the entrepreneur. Thus, the central entrepreneurial function, or activity, is to discover such exogenous entrepreneurial opportunities. For example, Stevenson and Jarillo (1990) assume that entrepreneurship is an orientation towards opportunity recognition. Central to the discovery research agenda are the questions “How do entrepreneurs perceive opportunities and how do these opportunities manifest themselves as being credible vs. being an illusion?”

By contrast, the earlier Schumpeterian (1942) tradition has a greater focus on the harnessing of entrepreneurial opportunities by the entrepreneur. The chief function of the entrepreneur is to innovate by combining resources in a novel manner, which creates opportunities that previously did not exist. In the creationist tradition, the entrepreneur does not merely discover entrepreneurial opportunities; rather, she creates them.

Why and how do some scientists become an entrepreneur, while others abstain? The answer to this question, which is at the heart of entrepreneurship theory, has generally revolved around the perception of opportunity and the means and willingness to act upon that opportunity.[1] But what is the source of such entrepreneurial opportunities? The view taken by the contemporary literature on entrepreneurship is no different. On the one hand is a prevalent view suggesting that entrepreneurship revolves around the recognition of opportunities and the pursuit of those opportunities (Venkataraman 1997). But the existence of those opportunities is, in fact, taken as given. The focus has been on the cognitive process by which individuals reach the decision to start a new firm. This has resulted in a methodology focusing on differences across individuals in analyzing the entrepreneurial decision (Stevenson and Jarillo 1990).

Krueger (2003, p. 105) has pointed out that "the heart of entrepreneurship is an orientation toward seeing opportunities," which frames the research questions "What is the nature of entrepreneurial thinking and what cognitive phenomena are associated with seeing and acting on opportunities?" This research agenda has triggered a debate as to whether entrepreneurs are simply born or can be "made." In either case, the discovery literature leaves the focus of the entrepreneurial decision clearly on individual-specific characteristics.

Thus, the discovery approach to entrepreneurship essentially holds the opportunities constant and then asks how the cognitive process inherent in the entrepreneurial decision varies across different individual characteristics and attributes (McClelland 1961). Shane and Eckhardt (2003, p. 187) summarize this literature in introducing the individual–opportunity nexus, "We discussed the process of opportunity discovery and explained why some actors are more likely to discover a given opportunity than others." Some of these differences involve the willingness to incur risk; others involve the preference for autonomy and self-direction, while still others involve differential access to scarce and expensive resources, such as financial-, human-, social-, and experiential capital.

Similarly, Kruger (2003) examines the nature of entrepreneurial thinking and the cognitive process associated with opportunity identification and the decision to undertake entrepreneurial action. The focal point of this research is on the cognitive process identifying the entrepreneurial opportunity which triggers the decision to start a new firm. Thus, a perceived opportunity and intent to pursue that opportunity are the necessary and sufficient conditions for entrepreneurial activity to take place. The perception of an opportunity is shaped by a sense of the

[1] In fact, the entrepreneurship literature has generally been sharply divided with respect to this question. Hebert and Link (1989) have identified three distinct intellectual traditions in the development of the entrepreneurship literature. These three traditions can be characterized as the German Tradition, based on von Thuenen and Schumpeter, the Chicago Tradition, based on Knight and Schultz, and the Austrian Tradition, based on von Mises, Kirzner and Shackle.

anticipated rewards accruing from and costs of becoming an entrepreneur. Some of the research focuses on the role of personal attitudes and characteristics, such as self-efficacy (the individual's sense of competence), collective efficacy, and social norms. Shane (2001a, b) has identified how prior experience and the ability to apply specific skills influence the perception of future opportunities.

The concept of the entrepreneurial decision resulting from the cognitive processes of opportunity recognition and ensuing action is introduced by Shane and Eckhardt (2003) and Shane and Venkataraman (2001). They suggest that an equilibrium view of entrepreneurship stems from the assumption of perfect information. By contrast, imperfect information generates divergences in perceived opportunities across different people. The sources of heterogeneity across individuals include different access to information, as well as cognitive abilities, psychological differences, and access to financial and social capital.

This approach focusing on individual cognition in the entrepreneurial process has generated a number of important and valuable insights, such as the contribution made by social networks, education and training, and familial influence. The literature certainly leaves the impression that entrepreneurship is a personal matter largely determined by DNA, familial status, and access to crucial resources. For example, Sarasvathy et al. (2003, p. 142) explain the role of entrepreneurial opportunity in the literature: "An entrepreurial opportunity consists of a set of ideas, beliefs and actions that enable the creation of future goods and services in the absence of current markets for them." Sarasvathy et al. (2003) provide a typology of entrepreneurial opportunities as consisting of opportunity recognition, opportunity discovery, and opportunity creation.

Still, the view of Sarasvathy et al. (2003) is that the entrepreneurial opportunity is exogenous from the cognitive process by which an individual weighs the decision to become an entrepreneur. By contrast, the Schumpeterian (1942) view suggests that economic agents make decisions that can create innovative activity. According to this view, the role of entrepreneurship is to create new opportunities by exploiting new knowledge from inventors. The most predominant theory of innovation, the resource-base view (Barney 1986; Alvarez 2003; Alvarez and Barney 2004), does not assume that opportunities are exogenous. Rather, innovative opportunities are the result of systematic effort by firms and the result of purposeful efforts to create knowledge and new ideas, and subsequently to appropriate the returns of those investments through commercialization of such investments (Cohen and Levinthal 1990; Griliches 1979). In what Griliches formalized as the model of the knowledge production function, incumbent firms engage in the pursuit of new economic knowledge as an input into the process of generating the output of innovative activity. Such efforts to create opportunities involve investments in research and development (R&D) and the enhancement of human capital through training and education. By analogy, scientists investing in their human capital through education, training, and research are essentially investing in their capacity to create new opportunities.

Thus, according to the Schumpeterian tradition, opportunities are endogenously created by purposeful and dedicated investments and efforts to create new knowledge. This is a stark contrast to the discovery tradition in the entrepreneurship literature where opportunities are taken as being exogenous and the chief entrepreneurial function is discovery.

As an alternative to the two polar cases of the discovery and creationist views, we instead suggest that the entrepreneurial opportunity, or the knowledge upon which the entrepreneurial decision is made, is in fact shaped by the context of the individual. In particular, the literature linking such entrepreneurial opportunities to the decision to become an entrepreneur has identified a broad spectrum of external settings. We distinguish among three main contexts – workers in firms, users of technologies, and scientists at universities, to focus on how the source of the entrepreneurial opportunity, or knowledge, shapes the actual entrepreneurial decision. Such a distinction across knowledge contexts may be important in that it sheds light on some of the great debates raging in the entrepreneurship, such as "Are entrepreneurs born or made?" The answer may be less about the former or the latter but more conditioned upon the context of the entrepreneurial opportunity, especially in the context of entrepreneurship in biotechnology.

## 9.3 Scientist Biotech Entrepreneurship

A context generating entrepreneurial knowledge involves scientists and other researchers in the academic or university setting, particularly in the field of life sciences research. A growing literature has tried to identify why some scientists enter into entrepreneurship, at least in the form of commercialization but more specifically by starting a new firm, while other scientists abstain. Some of these studies focus on the individual scientist in biotechnology as the unit of analysis (Zucker et al. 1998; Louis et al. 1989; Berkovitz and Feldman 2004; Audretsch and Stephan 1996). Thursby et al. (2001), and Jensen and Thursby (2001, 2004) identify both patents and the licensing of patents as important modes of scientist commercialization. In particular, Jensen and Thursby (2004, p. 1) employ a principal–agent framework in which the university administration is the principal and the faculty scientist is the agent, and identify that "whether or not the researcher remains in the university, and if so her choice of the amount of time to spend on basic and applied research, is complicated by the fact that she earns license income and prestige both inside and outside the university." Louis et al. (1989) identify the role of individual characteristics and attitudes, along with the norms of scientific peer groups, as an important factor in influencing the scientists' decision to commercialize their research in the form of a new-firm startup. Similarly, Shane (2004) and Lockett et al. (2005) focus on the scientist as the unit of observation in making the decision to become an entrepreneur.

Other studies focus on the new venture (implicitly or explicitly started by the scientist) (Nekar and Shane 2003; Audretsch and Lehmann 2005), or the university, which provides the institutional and cultural context (Lockett and Wright 2005; O'Shea et al. 2005; Di Gregorio and Shane 2003). However, what all of these approaches have in common is that they address the question "What leads a scientist to start a new firm?" The different units of analysis suggest a different focus on searching for an answer to this question, which may reflect a different underlying theory triggering a different source of entrepreneurial opportunity. Studies analyzing the unit of analysis of the scientist have been able to focus on scientist-specific characteristics, such as age, experience, citations, and publications. Studies based on the university as the analytical unit of observations have generally been unable to analyze the impact of scientist-specific characteristics, but instead have contributed a focus on the role of university-specific factors, such as the type of university and the role of the technology transfer office in shaping the decision of scientists to become entrepreneurs. By contrast, studies focusing on the new venture as the unit of analysis are able to shed more light on firm-specific strategies and characteristics, such as age, size, financial sources, and participation in strategic alliances, and link them to competitiveness or performance.

In virtually every study the nature of the entrepreneurial opportunity involves the commercialization of science. The meaning of commercialization varies across studies. The unanimity of the entrepreneurial opportunity reflects the singular activity of scientists engaged in research. Still, the question remains as to why some scientists choose to commercialize their scientific knowledge emerging from their research.

A large amount of literature has emerged focusing on what has become known as the appropriability problem (Cohen and Levinthal 1990). The underlying issue revolves around how firms that invest in the creation of new knowledge can best appropriate the economic returns from that knowledge (Arrow 1962). When the lens is shifted away from the firm to scientist as the relevant unit of analysis, the appropriability issue remains, but the question becomes: How can scientists with a given endowment of new knowledge best appropriate the returns from that knowledge? Stephan (1996) and Levin and Stephan (1991) suggest that the answer is “It depends” – it depends on both the career trajectory as well as the stage of the life cycle of the scientist.

The university or academic career trajectory encourages and rewards the production of new scientific knowledge. Thus, the goal of the scientist in the university context is to establish *priority*. This is done most efficiently through publication in scientific journals (Audretsch and Stephan 1996, 1999). By contrast, with a career trajectory in the private sector, scientists are rewarded for the production of new economic knowledge, or knowledge that has been commercialized in the market, but not necessarily new scientific knowledge per se. In fact, scientists working in industry are often discouraged from sharing knowledge externally with the scientific community through publication. As a result of these differential incentive structures, industrial and academic scientists develop distinct career trajectories.

The appropriability question confronting academic scientists can be considered in the context of the model of scientist human capital over the life cycle. Scientist life-cycle models suggest that early in their careers scientists invest heavily in human capital in order to build a scientific reputation (Levin and Stephan 1991). In the later stages of their career, the scientists trade or *cash in* this reputation for economic return. Thus, early in their career, the scientists invest in the creation of scientific knowledge in order to establish a reputation that signals the value of that knowledge to the scientific community.

With maturity, scientists seek ways to appropriate the economic value of the new knowledge. Thus, academic scientists may seek to commercialize their scientific research within a life-cycle context. The life-cycle model of the scientist implies that, *ceteris paribus*, personal characteristics of the scientist such as age should play a role in the decision to become an entrepreneur. In the early stages of her career, a scientist will tend to invest in her scientific reputation. As she evolves towards maturity and the marginal productivity of her scientific research starts to hit diminishing returns, the incentive for cashing in through entrepreneurship becomes greater.

Scientists working in the private sector are arguably more fully compensated for the economic value of their knowledge. This will not be the case for academic scientists, unless they cash out, in terms of Dasgupta and David (1994), by commercializing their scientific knowledge. This suggests that academic scientists become entrepreneurs within a life-cycle context.

An implication of the resource theory is that those scientists with a greater research and scientific prowess have the capacity for generating a greater scientific output. But how does scientific capability translate into observable characteristics that can promote or impede commercialization efforts? Because the commercialization of scientific research is particularly risky and uncertain (Audretsch and Stephan 1999), a strong scientific reputation, as evidenced through vigorous publication and formidable citations, provides a greatly valued signal of scientific credibility and capability to any anticipated commercialized venture or project.

This life-cycle context presents two distinct hypotheses: both age and scientific reputation, which reflect and signal the underlying scientific human capital of the scientist, should influence the decision of a university scientist to engage in commercialization activities.

Thus, a number of studies have tried to link the propensity of a university-based scientist, with a particular focus in biotechnology, to start a new firm, or become involved with a start-up, to scientist-specific characteristics, such as age, experience, and gender. In particular, Audretsch and Stephan (1996, 1999) find that the propensity for university scientists to start a new biotechnology company is lower for younger scientists and higher for more mature scientists. By contrast, scientist spin-offs from pharmaceutical corporations exhibit less of an age effect. The mean age of scientists starting a new biotechnology startup is considerably lower when the scientist had been employed by a pharmaceutical corporation than at a university. This is consistent with the scientist life-cycle theory of academic scientist commercialization behavior.

Similarly, several studies have linked scientist reputation to the propensity to start a new biotechnology firm. Zucker et al. (1998) find that a reputation as a star scientist, as measured by citations, increases the likelihood of a university scientist starting a biotechnology firm. Zucker et al. (2002) found similar results using the commercialization measure of patents. Similarly, Audretsch and Stephan (1996, 1999) link the propensity for a university scientist to work with a new biotechnology start-up or start a new firm herself to three different measures of reputation – publications, citations, and recipient of a Nobel prize. All three reputation measures are positively related to the likelihood of a scientist becoming an entrepreneur. Studies linking scientific-specific characteristics, such as age, citations, and publications, have been generally restricted to those analyzing the unit of observation of the individual scientist. There is compelling evidence that not only scientific reputation, as measured by citations and publications, but also being the recipient of a Nobel prize is complementary to and not a substitute for entrepreneurial activity. However, as Levin and Stephan (1991) point out, these relationships are not neutral with respect to the stage of a scientist's career but may tend to happen sequentially.

Scientist location can influence the decision to commercialize for two reasons. First, as Jaffe (1989), Jaffe et al. (1993), Almeida and Kogut (1997), and others show, knowledge tends to spill over within geographically bounded regions. This implies that scientists working in regions with a high level of investments in new knowledge can more easily access and generate new scientific ideas. This suggests that scientists working in knowledge clusters should tend to be more productive than their counterparts who are geographically isolated. A number of studies confirm that the geographic location of a scientist influences the propensity to become an entrepreneur (Zucker et al. 1998, 2002; Audretsch and Stephan 1996, 1999). In particular, the studies of both Audretsch and Stephan (1996, 1999) and Zucker et al. (2002) found that location plays a crucial role in influencing the entrepreneurial decision to start a new company in biotechnology.

A second component of externalities involves not the technological knowledge, but rather social capital. A large and robust literature has emerged attempting to link social capital to entrepreneurship (Aldrich and Martinez 2003; Thorton and Flynn 2003; Powell et al. 1996; Sorenson and Audia 2000; Sorenson and Stuart 2001). According to this literature, entrepreneurial activity should be enhanced where investments in social capital are greater. Interactions and linkages, such as working together with industry, are posited as conduits not just of knowledge spillovers but also for the demonstration effect providing a flow of information across scientists about how scientific research can be commercialized (Thursby and Thursby 2004). As Bercovitz and Feldman (2004) show in a study based on the commercialization activities of scientists at Johns Hopkins and Duke University, the likelihood of a scientist engaging in commercialization activity, which is measured as disclosing an invention, is shaped based on the commercialization behavior of the doctoral supervisor in the institution where the scientist was trained, as well as the commercialization behavior and attitudes exhibited by the chair and peers at the relevant department.

Similarly, Audretsch et al. (2006) examine the propensity for university scientists to commercialize by analyzing new databases consisting of the top scientists involved in biotechnology research. Three distinct measures of social capital are linked to the likelihood of a scientist starting a new venture, copatenting with other academic scientists, copublishing with industry scientists, and serving on an industry board of directors or a scientific advisory board. All three measures of social capital found to have a positive impact on the likelihood of a scientist becoming an entrepreneur.

The university context has also been found to shape scientist entrepreneurial knowledge. On the basis of a study of 778 faculty members from 40 universities, Louis et al. (1989) find that it is the local norms of behaviour and attitudes towards commercialization that shape the likelihood of an individual university scientist to engage in commercialization activity, in their case by starting a new firm. This would suggest that university-specific rules, norms, and culture, especially in terms of local behaviour and attitudes, help to shape scientist entrepreneurial knowledge.

Di Gregorio and Shane (2003) use the data from the Association of University Technology Managers database to analyze 503 start-ups spun out from 101 universities. Di Gregorio and Shane (2003) identify two university-specific factors that are conducive to university spin-offs. The first involves the quality of the faculty. The second is the institutional ability enabling both the university and the scientist to take an equity stake in the new venture in lieu of licensing fees. Similarly, O'Shea et al. (2005) identify that the past success of a university in transferring technology creates path dependence in generating scientific entrepreneurial opportunities. Franklin et al. (2001) identify the differential impact of the older, more traditional British universities from the newer ones. They find that while the more traditional universities are stronger in terms of academic research, the newer British universities have an entrepreneurial advantage. In a subsequent study, Lockett et al. (2003) link university strategy to the number of entrepreneurial spin-outs from the university.

Other studies have focused on that role of university-specific institutions, such as the technology transfer office (TTO), in influencing scientist entrepreneurial knowledge. Lockett and Wright (2005) link characteristics of the TTO to university spin-off activity. Using the resource-base view, they find that universities investing more in intellectual property protection capabilities and the business capabilities of the TTO generate a higher number of spin-offs.

Markman et al. (2005) examine the relationship between university spin-off activity and university-based incubators, as intermediated via the TTO. Similarly, Markman et al. (2004a, b) link university spin-offs to a broad spectrum of TTO-specific characteristics, such as speed in processing the technology transfer, involvement of faculty, competency in identifying licensing, and TTO resources.

Most of the studies identified above are typical of a growing literature that has emerged trying to gauge and analyze the extent to which university research spills over into commercial activity. Much, if not most, of this previous research has been restricted to focusing on the activities emanating from TTOs, which have provided systematic and consistent documentation of their efforts over a fairly long period of time. Analyses of these data have typically led to conclusions suggesting that while patents and licenses from university research have increased over time, the typical TTO does not generate significant commercialization of university research. However, an important qualification is that by restricting themselves to TTO-generated data, such studies are not able to consider any commercialization activities not emanating from the TTOs.

In their 2006 study, Audretsch et al. take a different approach examining the determinants of entrepreneurship in the biotechnology context. Rather than focus on what the TTOs do, their study focuses on what university scientists engaged in biotechnology research do. Thus, the findings about the commercialization of university research are based on actual university scientists and not the TTOs. The results are revealing. In particular, while all modes of commercialization are important, scientist entrepreneurship in biotechnology emerges as an important and prevalent mode of commercialization of university research. More than one in four patenting NCI scientists has started a new firm. This is a remarkably high rate of entrepreneurship for any group of people, let alone university scientists. Thus, the extent to which university research is being commercialized and entering the market may be significantly greater than might have been inferred from studies restricted only to the commercialization activities of the TTO. They suggest that scientist entrepreneurship may prove to be the sleeping giant of university commercialization.

Second, the mode of commercialization is apparently not independent on the commercialization route for biotechnology scientists. Nearly one third of patenting biotechnology scientists rely on the entrepreneurial commercialization route, in that they do not assign all of their patents to the university. These scientists exhibit a higher likelihood of starting a new firm but a lower propensity to license. By contrast, biotechnology scientists choosing the TTO commercialization route exhibit a higher propensity to license but a lower likelihood to start a new firm.

## 9.4 Conclusions

The theories and empirical evidence examining the sources of entrepreneurial knowledge suggest something of a mixture between the two dichotomous discovery and creationist views. On the one hand, as the theories and empirical evidence highlighting the role that scientist human capital plays in the entrepreneurial decision suggest, those scientists creating more scientific knowledge have a higher likelihood of becoming entrepreneurs as well. This would suggest that such highly productive scientists are not passive vehicles in which the entrepreneurial opportunity falls like “manna from heaven.” On the other hand, the theories and empirical evidence linking social capital, and locational and institutional factors to scientist entrepreneurship suggest that there are numerous mechanisms facilitating the discovery process of an existing entrepreneurial opportunity. Thus, when it comes to entrepreneurial knowledge for scientists, neither the extreme Kirznerian nor the Schumpeterian view fully accounts for the source of entrepreneurial opportunities. Rather, the source of entrepreneurial knowledge for scientists is something of a hybrid – part creation and part discovery. Still, compared to entrepreneurial opportunities for workers and users, such entrepreneurial knowledge has a greater component of being created by scientists rather than discovered.

This would suggest that future research designed to guide public policy should not be limited to those modes of biotechnology commercialization that are publicly available and can be relatively and easily accessed at low cost. Scientist patent activity and participation in the SBIR program are certainly important modes of commercialization in biotechnology, but their ease of access should not lead to the conclusion that they are even the most important and prevalent forms of commercialization. Rather, other modes of commercialization for which no systematic comprehensive public sources of data exist, such as scientist new-firm startups, may also be a highly prevalent and important form of scientist commercialization in biotechnology. Future research needs to explore other modes of commercialization and undertake the painstaking data collection to provide systematic measurement and analysis of commercialization conduits such as the start-up of new firms.

It is imperative that comprehensive and systematic new sources of measurement be created by directly interacting with the scientists themselves to gauge the extent, nature, determinants, and impact of scientist commercialization of research. If the commercialization of science, particularly in fields such as biotechnology, represents one of the missing links of economic growth, job creation and competitiveness in global markets, undertaking the painstaking measurement and analysis is essential to guide public policy in both understanding and promoting this important source of economic growth.

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