24 Innovation and the evolution of industries: a tale of incentives, knowledge and needs

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INTRODUCTION

This chapter is about the co-evolution of technology and markets. Since our goal is to understand the way these forces impact the advancement of industry, these cannot effectively be independently analyzed.

Classical economists recognized that the link between technological evolution and market forces is the trigger of industrial revolution, as well as the consequential tumultuous process of economic growth: 'In turning from the smaller instruments in frequent use to the larger and more important machines, the economy arising from the increase of velocity becomes more striking' (Babbage, 1832, pp. 4–36). However, Adam Smith noted that the use of 'more important machines' is limited by the extent of the market. He described the combined effect of innovation, which creates new markets, and of new markets, which creates incentives for innovation. Karl Marx highlighted the role of machines as the main source of productivity increases as well. Marx also recognized that low wages lead to demand shortages.

Despite the awareness of the classical economists, the analysis of the co-evolution of technology and markets as the principal determinants of industrial dynamics is abandoned in traditional neoclassical theory.

A certain extension of this approach is found only in the search for incentives responsible for the direction and nature of technological progress. The so-called demand-pull approach looks at the demand side of the economy, considering product innovations as initiated by demand. On the other hand, changes in relative prices are considered responsible for certain factor-saving directions taken by technological progress.

Conversely, the role of technology is completely removed from the realm of the discipline: technological progress is treated as an exogenous variable and is therefore banned from the extra-economic sphere. For this reason, these approaches are not explicitly discussed here. These factors are characterized by the assumption of reactive behavior as used in neoclassical economics for all kinds of exogenous changes (preferences, relative factor price changes, income changes etc.). The economic processing of technological changes does not signify anything, but simply follows the market forces in which economic development is pushed by an exogenous technology shock. Within this theoretical frame, the emphasis on technological progress as the most important source of economic dynamics is of no use analytically because, as a black-box phenomenon, technological progress eludes economic interpretation.

Regardless of whether technological-push or demand-pull approaches are considered, typically both actors react only to economic changes. New technological know-how is a pure public good that each economic actor can appropriate at no cost and which is

– externally to the economic sphere – generated (invention) and adapted for economic purposes (innovation). Therefore innovative activities and the existence of spillover effects constitute no economic problem at all.

In this chapter, we review and discuss contributions that consider innovation both as a key factor of advancement and as an endogenous dimension of any economic system. The chapter consists of two focused discussions.

The next section discusses the evolution of technology and markets from the firm perspective. The emergence of new industrial economics takes into account the notion that firms or actors consciously and actively invest resources in order to achieve new technological know-how useful for economic purposes. Consequently, technological progress becomes an endogenous phenomenon, i.e. it is based on economically motivated decisions. Compared to traditional neoclassical economics, the new industrial economics performs much better in analyzing the importance of technological progress. However, in an effort to achieve static equilibrium solutions, it sacrifices some important aspects.

The third section highlights the role of the demand side in shaping competitive conditions and technological trajectories. We review two streams of literature concerning this issue. The first conceives of demand as a pure incentive effect, as in the neoclassical tradition. The second regards demand as a possible source of innovative ideas.

Within each section, we shall proceed symmetrically. Indeed, both technology-push and demand-pull contributions are neither monolithic nor homogeneous; a second divide intersects both streams of literature. There is a cross-section of literature both consistent with mainstream economics and focused on the monetary incentive of the firm to innovate. On the firm side, this is translated into the analysis of the impact of markets and institutions on the rewards of innovation. On the demand side, this framework results in the analysis of market size as the main pull mechanism.

A second approach deviates from mainstream economics, sacrificing the analytical tractability of the issues and highlighting the role of knowledge embedded in the innovation process. Therefore the focus is on the learning process within firms as a necessary condition for innovation. The demand side here is conceived as a flow of information from users and consumers to producers.

The organization of the chapter will reflect the historic structure of the literature. Specifically, this chapter shows how these approaches emerged, the critiques each confronted and, finally, their refinement. The conclusions also reveal future challenges in the field of the economics of innovation.

SUPPLY AND INNOVATION

Why do firms engage in innovative activities and invest in R&D? How are these activities related to the firm environment in general and specifically to the structure and dynamics of the market/industry?

Firms engage in innovative activities if they see an economic or technological opportunity. Analytical approaches construe these two aspects quite differently. The differences first accrue to the assumptions about the behavior of the economic actors and the ability of each to identify or to anticipate those opportunities. Second, there are sizable differences in the consideration of economic chances and of technological opportunities. On this basis, we can distinguish roughly two main camps: the first, based on neoclassical thinking, assumes perfectly rational agents whose only task is to design optimal R&D projects. On this approach, technological opportunities are always there and have only to be exploited, or as Dasgupta and Stiglitz (1980a, p. 272, fn. 1) put it: 'It is as though Mother Nature has a patent on all techniques of production . . . and that society has to pay x to purchase the right to use the technique of production . . .'. In this sense, the intensity and direction of innovative activities depend entirely on the economic incentives offered, mainly the potential of the profit. These profits in turn are dependent on the competitive situation facing a firm and are partially intertwined with the conditions for appropriating innovation rents and hence technological spillovers.

The other camp renders innovative agents boundedly rational in the sense that each neither has all information at hand nor is well equipped to solve each problem (Simon, 1955). In this sense, agents need to explore technological opportunities for innovative success, and require respective knowledge and competencies. The availability of each governs the intensity and direction of innovative activities. The ways actors acquire and build up these competencies and transform them into competitiveness are at the core of the analysis. Market conditions providing the financial resources for appropriate investments are crucial; technological spillovers are considered more a device for learning than a source of profit-diminishing imitation. Summing up, we can distinguish between incentives-based and knowledge-based theories. The following subsections will discuss both in detail.

Innovation and Economic Incentives

The origins: Schumpeter and first IO analyses

When addressing innovation activities of firms in industrial organization (IO), the neo-Schumpeterian hypotheses are an obvious point of departure. Schumpeter, in *Capitalism, Socialism and Democracy* (1943), postulates that large firms are the main driver of innovations and technological change (Schumpeter Mark II). In the alternative Schumpeter approach, formulated in *The Theory of Economic Development* (1912), entrepreneurs and therefore small firms are considered the engine of innovative change (Schumpeter Mark I). This Schumpeterian controversy led to the two neo-Schumpeter hypotheses. The first focuses on the firm and suggests that large firms are more innovative than small firms. The second argues on the basis of industry or market structure that innovation activities are more intense in more concentrated sectors. Finally, these hypotheses were taken up by industrial economics from the 1960s onward and were discussed first within the structure–conduct–performance approach of IO.

The seminal work by Arrow (1962) is considered the first approach to look at the relationship between the benefits accruing to innovative activities and the R&D costs involved in the context of different market structures. His analysis looks at the economic incentives of the actors to engage in R&D activities under alternative market structures. To make that analysis as simple as possible, he compares a monopoly and a situation of perfect competition in which innovative activities do not alter the respective market structure. Arrow shows that the differential profit in the case of perfect competition is always larger than that in the monopoly. The reason is to be seen in a lower profit in the case of the monopoly: the profit after innovation partly replaces the profit before

innovation. In the case of perfect competition, this replacement does not apply, and the full amount of innovation rents is gained. Consequently, the economic incentives for innovative activities are higher in perfect competition than in monopoly, so one should expect more intense innovation in the former case. Hence Arrow falsifies the Schumpeter hypotheses within this IO framework.

Besides the criticism of Demsetz (1969), who identifies the non-comparability of the situations of monopoly and perfect competition within the Arrow approach, other criticism refers to the purely static character of the analysis as well as to the neglect (i) of the interdependence of market structure and innovative activities (Reinganum, 1989; Gilbert and Newberry, 1982); (ii) of oligopolistic competition (by focusing only on monopoly and perfect competition) (Dasgupta and Stiglitz, 1980a); and (iii) of technological interdependencies among innovators and (potential) imitators (Levin and Reiss, 1984).

The economics of R&D and new industrial economics

The latter three issues are taken up by the approach of new industrial economics by addressing the issues of the incentive to innovate, the bidirectional influence of the market structure, and the role of technological spillovers. The analyses are mainly of a game-theoretic type, where strategic choices of profit-maximizing firms refer not only to quantity or to price but also to R&D expenditures. The equilibrium-oriented modeling approach allows for welfare analysis by investigating the private and the social gains from innovative activities.

The models developed can be distinguished by the way (i) R&D expenditures affect innovation; and (ii) market competition and market structure are taken into account. Regarding the effect of R&D expenditures, three alternative lines of research have been taken: one states that the level of R&D is positively correlated to the economic reward (e.g. Dasgupta and Stiglitz, 1980a; Levin and Reiss, 1984); a second approach relates the level of R&D to the likelihood of success (e.g. Sah and Stiglitz, 1987); and a third line suggests a negative relationship between the level of R&D and the time to introduce a new product or new process (e.g. Dasgupta and Stiglitz, 1980b; Kamien and Schwartz, 1980). As modeling devices, non-tournament models assume either a non-monopolistic or endogenous market structure, whereas in tournament models (as well as in contest models) innovation competition allows only for one winner and thus always leads to a monopoly.

Contest models A core issue in understanding innovation incentives is the relationship between the appropriability of innovation rents and the rate of technical progress. That is addressed in so-called contest models. Here firms announce R&D expenditures, allowing them to create an innovation, and then protect it with a patent, thereby allowing the earning of economic rents. These models show that the announced level of R&D is lower, the lower the degree of patent protection, and hence the incentive to engage in innovation is reduced (Witt, 1987). These models can be criticized on two grounds: first, as these are deterministic (e.g. Barzel, 1968; Scherer, 1967; Dasgupta and Stiglitz, 1980b; Gilbert and Newberry, 1982; Katz and Shapiro, 1985), they can be interpreted as auction models, where competing firms make offers and only the winner of the auction will then manage R&D activities (e.g. Dasgupta and Stiglitz, 1980b). It is quite obvious that this pattern is not a 'race'; the competitive aspect here refers to a potential competition

– which might be quite 'tough' (Reinganum, 1989, p. 855). Second, the appropriability conditions for innovation rents depend not only on the public-good character of know-how, but also on the market structure after innovation. Two separate lines of modeling take up these two aspects: non-tournament models and patent races.

Non-tournament models Dasgupta and Stiglitz (1980a) criticized Arrow (1962) and suggested a model in which R&D competition and innovation were modeled as non-tournament. Many competing firms producing homogeneous outputs spend R&D to generate technologically equivalent and perfectly protected improvements of their respective production technologies, leading to lower unit costs. The incentive to spend on R&D activities does not depend on possible imitative activities of competitors, but on market structure and the features of technology. Therefore technological-innovation-related revenues are determined by the economic interdependence of the firms. Within a competitive surrounding allowing for market entry innovation, revenue will be zero in market equilibrium.

Given these assumptions, a number of relationships between market size and R&D decisions can be deduced. Generally valid results cannot be found in this model, only solutions dependent on certain parameters of demand and unit cost elasticity. In most cases, however, the rate of progress is greater in markets with a higher degree of monopoly. Schumpeter's argument of a positive relationship between market power and innovation rate seems here to be validated.

Technological spillovers are discussed in Levin and Reiss (1984), Spence (1984) as well as d'Aspremont and Jacquemin (1988), who enhance the Dasgupta and Stiglitz framework. Both Levin and Reiss (1984) and Spence (1984) show that spillover effects generally lead to a reduction of individual R&D expenditures and therefore have a negative incentive effect on R&D, with the exception of complementary R&D projects. Despite the incentive-reducing effect, spillovers reduce inefficiencies due to R&D duplication and enhance welfare. D'Aspremont and Jacquemin (1988) show this to take place when the intensity of spillover effects is high.

Tournament models or patent races Non-tournament models attempt to explain how market forces influence R&D levels and rates of technological progress. However, these models do not discuss any strategic behaviors implemented by actors to defend their technologically or economic leading positions. In addition, patterns such as creative destruction (Reinganum, 1985) and success-breeds-success (Dasgupta, 1986) are not taken into account. On the contrary, tournament or patent race models do exactly that.

In these models, technological competition is interpreted as a race for a certain patent. The firm that introduces an innovation first enjoys patent protection and the resulting temporary monopoly. Investing in R&D activities is meant to increase the probability of success earlier than competitors. For the 'losers', the R&D expenditures spent are lost. The level of investments depends on two effects that impinge upon the expected rewards: the profit motive and the competitive threat. The former consists of the difference between the profit before and after successful innovation. The latter ensues by comparing the profit in the case of a successful innovation and the profit in the case in which the competitor wins. Both differences should be positive for an innovative engagement to be considered worth being pursued.

The interplay of these two effects generates asymmetric incentive structures for the incumbent monopolist and other firms willing to enter the market. Reinganum (1985) shows that, in the case of a drastic innovation, the incumbent and the potential entrant face the same competitive threat, whereas the incumbent's profit motive is much smaller (as the current monopoly profit is challenged). Hence the follower has a greater incentive to engage in R&D, which increases the probability of success, and the monopoly position consequently is more likely to change from the incumbent to the entrant, the case of creative destruction. In case of a non-drastic innovation, however, the incumbent invests more in R&D because it faces a greater competitive threat. Thus it will have a higher probability of success and of keeping the monopoly position. Taking into account technological spillovers between firms reinforces the tendency for creative destruction and weakens the continuation of monopoly position.

Extending the analysis to include the success-breeds-success pattern – as opposed to the leapfrogging pattern – requires a dynamic model with a sequence of several patent races. Reinganum (1985) also analyzes the case of a sequence of patent races. For drastic innovations, the respective patent races in the sequence are independent of each other, so that the sequential character of the model is not essential and static solutions apply. For non-drastic innovations, however, this independence does not hold, and winning a specific patent race is not just worthwhile for profit reasons but also for gaining strategic advantages for future races.

Drawing on stochastic models, only in a few cases are they analytically solvable, and simulation techniques as in Beath et al. (1989) need to be applied. In set-ups where spillover effects among firms are restrained, backward firms are not able to compete for the same stage within the innovation sequence as the leading firms. However, they 'approach' step by step the position of the leading firms. These are the catch-up type of models. Beath et al. (1989) combine the R&D decision with Bertrand and Cournot behavior on the market. Their simulation analyses show that Bertrand behavior tends to reinforce dominance and thus the catch-up type. Otherwise, Cournot behavior sustains leapfrogging.

Innovation and the Generation of New Knowledge

Empirics first: the neo-Schumpeter hypotheses revisited and other regularities

We now leave the realm of the incentives-based theory to move toward a more empirically grounded and knowledge-based approach to industrial dynamics. IO research addresses the neo-Schumpeter hypotheses mainly from a theoretical point of view. Associated empirical work on the validation of these hypotheses provides weak evidence for the hypothesis that large size or concentrated markets lead to greater innovative activities. Instead, other industry- or technology-specific factors show larger explanatory power. Including other variables, such as technological opportunity and conditions of appropriability, leads to a drastic reduction in the significance of the coefficients for concentration. Particularly in the context of the neo-Schumpeterian hypotheses, the variance of R&D intensity is barely explained by the concentration variable, whereas the industry variable explains 32 percent. In other studies, 4 percent of variance is explained by concentration, whereas more than 50 percent is explained by variables representing demand, opportunities and appropriability (Levin et al., 1985). Consequently, technological characteristics, demand-side characteristics (e.g. product diversification), as well as aspects of strategic interaction (e.g. intensity of price competition), show higher validity than the factors central to the hypotheses tested. In addition, a causality problem is involved in interpreting these empirical findings, as it is not clear whether innovative activities determine structural variables or the other way round. As a consequence, the application of a dynamic view on industrial innovative activities promises better results with respect to the changing and complex causality relationships.

Moreover, other empirical works highlight facts (often already labeled as stylized facts) related to the dynamics of entry and exit (Geroski, 1995; Audretsch, 1995; Doms et al., 1995; Malerba and Orsenigo 1997; Klepper and Simons, 2005; Cantner et al., 2009, 2010), to market turbulence, to the persistence of firm performance differences (Mueller and Cable, 2008; Auerswald, 2010; Caves and Barton, 1990; Cantner and Krüger, 2004), to the size distribution of firms, to patterns of firm growth (Simon, 1955; Ijiri and Simon, 1977; Bottazzi and Secchi, 2006; Cefis et al., 2007), and to a long-term perspective, just as in the industry life-cycle discussion.

These dimensions of the dynamics of industries infer that structural characteristics used traditionally, such as firm size and age, the intensity of competition (market concentration) and barriers to entry (scale economies etc.), are only partially able to explain the dynamics of firms and industries. As these rather incentive-based factors seem unable to fully account for industry dynamics, an alternate line of research emerged, focusing on the knowledge and capabilities of actors and firms as well as on the search and learning processes involved in building them. The approach directly addressing four characteristic of technology – opportunities, appropriability conditions, cumulativeness of technological change, and the specific nature of knowledge – is known by the acronym OACK.

OACK serves as a basis for investigating industrial dynamics and industrial evolution by looking at innovative activities and market structure as complex and mutually dependent phenomena. It further finds that the various ways agents compete and the level of competition itself depends on the degree of heterogeneity of innovative activities and successes. The heterogeneity across firms in innovation implies both the presence of idiosyncratic capabilities (absorptive, technological, etc.) and that firms not only do different things but, and most importantly, when they do the same thing, they know how to do it in different ways. This focus on the underlying capabilities for innovation activities alludes to behavioral foundations and the innovations' embeddedness in the prevailing technological environment. We now describe how the OACK approach has been useful to classify innovative activities.

Innovative patterns and their classification in the OACK approach

Understanding innovative activities requires opening up the black box (Rosenberg, 1976) in which actors both acquire and apply new concepts in order to create new combinations. A first step is to briefly address the rather general pattern of the innovation process in modern manufacturing, as suggested by Dosi (1988):

1. Endogeneity of innovative activities
2. Uncertainty
3. Partial dependence on contacts to science

4. Learning-by-doing, learning-by-using, learning-by-innovating, learning-by-inventing
5. Cumulativeness.

Features (1) and (2) point to the fact that economic actors (primarily firms) are engaged in innovation and are thereby confronted with strong and therefore non-calculable uncertainty (Knight, 1921; Arrow, 1991). This implies that designing optimal R&D methods is impossible and that the search for new ideas is a trial-and-error process. Hence an understanding of the economic agent different to the *homo oeconomicus* is required. Drawing on Simon (1955), we use the concept of bounded rationality, which questions the assumption of ubiquitous information (substantial rationality) available to agents, as well as the assumption of unbounded capabilities (procedural rationality) to use this information. The resulting notion of bounded rationality seems to be especially relevant, for actors are engaged in innovative (and imitative) activities. The act of creating something new, as an experimental activity, is essentially linked to imperfect information and imperfect abilities to use it.

The notion of bounded rationality entered the theory of the firm with Cyert and March (1963) as stable behavioral traits, and with Nelson and Winter (1982) when they added the concept of routines, a form of adaptive control with a more flexible behavior. Routines are behaviors that show stability over time as they are based on idiosyncratic knowledge and competencies. Routines change, however, if the rewards do not reach the desired level. A further strategic dimension of routines has been developed within the dynamic capability view of the firm (DCV), as introduced by Teece (1988) drawing on the resource-based view of the firm (e.g. Penrose, 1959; Wernerfelt, 1984). The inherent distinctive knowledge and competencies of individual firms are simply seen as a major resource (characterized as being valuable, rare, imperfectly tradable and non-substitutable) contributing to competitiveness. Since these resources are developed and implemented over time, these are termed dynamic capabilities in order to stress their role in long-term strategic planning. Other firms must incur non-negligible costs and build up respective absorptive capacities (Cohen and Levinthal, 1989) in order to try replicating the knowledge and competencies these capabilities represent.

Features (3) to (5) fit into the dimension of the OACK approach. These indicate how innovative actors act in this trial-and-error process. Actors gain information and expertise from the learning process and then build up dynamic capabilities. The latter, in turn, enables exploration of new opportunities and exploitation of existing ones (Rosenberg and Nelson, 1994, Zucker et al., 1998; Mowery et al., 2004). To the extent that learning relates to the accumulation of personal experience, actors are diverse in terms of their technological (as well as economic) knowledge. As an important consequence of this heterogeneity, the traditional conception of knowledge as a quasi-public good (Arrow, 1962) must be reconsidered. Knowledge seems to have a tacit component (Polanyi, 1967) and, therefore, may not be transferable at all (Cowan et al., 2000) or only at a certain price as a latent public good (Nelson, 1991). These features increase the appropriability of knowledge and reduce the importance of patent protection, otherwise prominent in traditional approaches. Because of the stickiness of knowledge, the social dimension of learning assumes a central role and the means by which knowledge is extracted from external sources such as science or competitors becomes crucial.

Based on the elements of the OACK approach and combining them with the general pattern of innovation in manufacturing, several broad classifications are suggested to deal with emerging patterns. Two of them, by Pavitt (1984) and by Malerba and Orsenigo (1995, 1997), are prominent.

The Pavitt classification distinguishes by sector-specific organization of innovation activities and the specific features of technological change. In the end, four different classes are identified: science-based industries; supplier-dominated industries; production-oriented industries with specialized suppliers; and scale-intensive sectors. This classification accounts for a first clear relationship between the way firms organize the activities to create/use new know-how and the structural dimensions of the sector in which they work.

The classification by Malerba and Orsenigo is oriented toward linking the pattern of innovation activities with the pattern of learning in firms. This exercise leads to two classes of sectors or so-called regimes. A first class contains sectors of an entrepreneurial regime with a larger number of predominantly small firms, low market concentration and market turbulence, easy market entry and exit, and low stability in the ranking of innovators (Schumpeter Mark I). These features are related to high technological opportunities, weak conditions of appropriability and a low degree of cumulativeness of technological knowledge. Consequently, market competition is intense and always fed by new ideas from within and from outside (entering firms) the market.

The sectors of the second class belong to a routinized regime. Large firms are more frequent, operating in more concentrated markets with low market share turbulence, high stability in innovator ranking, and a low market entry rate. The appropriability conditions for new knowledge are considerably high, and knowledge is intensively cumulative. As a result, we observe a considerably low intensity of competition among firms pursuing innovation activities in a routinized way, continuously building up competitive advantage in a success-breeds-success manner.

This difference in the organization of innovative activities across industries may be related to a fundamental distinction between Schumpeter Mark I and Schumpeter Mark II models. Schumpeter Mark I is characterized by 'creative destruction', with technological ease of entry and a major role played by entrepreneurs and new firms in innovative activities. By contrast, Schumpeter Mark II is characterized by 'creative accumulation', with the prevalence of large established firms and the presence of relevant barriers to the entry for new innovators.

Technological regimes and Schumpeterian patterns of innovation change dynamically over time. According to an industry life-cycle view, the Schumpeter Mark I pattern of innovative activities may turn into a Schumpeter Mark II pattern (Klepper, 1996), but in the presence of a major technological discontinuity, a Schumpeter Mark II pattern may be replaced by a Schumpeter Mark I. If we introduce into the evolution of industry the role of both technology and knowledge, the dynamic features of system need also a revision.

Industrial Dynamics

Industry dynamics refers to an approach that looks at the change of industries over time (Malerba and Orsenigo, 1996) where innovative activities are a major driver of the dynamics.

Basic dynamic mechanisms and pattern

Combining the elements of the OACK approach with the behavioral foundations of innovative activities suggests that 'different agents (firms) know how to do different things in different ways (domains, levels of performance, etc.)' (Malerba and Orsenigo, 2000, p. 295). Consequently, the heterogeneity of firms in a sector or market can be related to differences in knowledge and competencies acquired over time. Those differences contribute to differential competitiveness and successes.

In this sense, the knowledge and competence specificities of firms are the major determinants of the industrial structure and its evolution over time. Two kinds of mechanisms driving that dynamics of industries have been identified: (1) mechanisms leading to the advance of knowledge and to the generation of innovations and (2) mainly market-based mechanisms for selecting between different new combinations. The interdependency of these two mechanisms will be discussed in the next section.

First, the cumulativeness of knowledge due to a firm-specific process of learning leads to a specific, path-dependent development of individual firm competencies. This specificity generates differences in firm performance, and path dependency makes it difficult for a follower to catch up to the leaders. Such a dynamic is labeled success-breeds-success, a term first used by Phillips (1971) to explain the development of the airplane industry. The success-breeds-success progression can be mitigated when agents can learn from others or imitate. This implies that backward firms can catch up to the knowledge or innovation leader (Verspagen, 1992; Cantwell, 1993). Complete equality or even overtaking may be constrained either by imperfect transferability of tacit knowledge (Polanyi, 1967) or by the lack of absorptive capacities (Cohen and Levinthal, 1989) by the lagging firm.

Second, firm heterogeneity caused by different innovative successes requires an understanding of market competition different from the allocative conception in neoclassical economics. Markets in this context are seen as a platform upon which competition among heterogeneous agents or better heterogeneous products takes place. With respect to innovation activities, different ideas and the different knowledge stocks and competencies behind them are in competition (Metcalfe, 1994; Nelson and Winter, 1982).

In this context, markets serve a twofold purpose. First, markets are a selective mechanism and work efficiently if, step by step, poorly performing ideas are eliminated and better ideas allowed to survive. The second aspect refers to Hayek's notion of competition as a discovery process, which allows firms to learn more about the viability of new ideas. This leads to a more complete picture, as the success of the market or failure of a firm provides information about the comparative evaluation of the product or new idea. This information can be used to adjust and to design further innovation activities. In this sense, the aforementioned search and learning mechanism is nicely combined with the mechanism of selective competition.

The concert of mechanisms

In the view of the empirical findings presented above and the literature on the behavioral foundations of innovative agents, there have been various attempts to formally analyze these phenomena. We briefly mention those that look at dynamics and at innovation. A first group of models attempts to reconcile the empirical regularities with the equilibrium approaches of industrial organization (e.g. Jovanovic, 1982; Ericson and Pakes, 1995; Sutton, 1998), thereby leaving out heterogeneity of actors or learning processes.

A second group of models deviates from equilibrium analysis and takes more of an evolutionary or neo-Schumpeterian perspective. The modeling exercises have analytical solutions only when the set-up is rather simple. However, more complicated relationships and the representation of heterogeneous agents with idiosyncratic paths of development often require simulation techniques to identify characteristic patterns of development. This group contains models in the evolutionary tradition of Nelson and Winter (Nelson and Winter 1982; Dosi et al., 1995), industry life-cycle models (Klepper, 1996, 2002; Klepper and Simons, 2000), history-friendly models (Malerba et al., 1999; Malerba and Orsenigo, 2002), and more macro-level models, by linking innovation and industry evolution to structural change and the changing sectoral composition of the economy (Metcalfe, 1998; Dopfer et al., 2004; Dosi, 2001; Saviotti, 1996).

Innovation–market feedbacks In general, these models are based on the feedback effects between market competition and innovation activities (e.g. Mazzuccato and Semmler, 1999; Cantner et al., 2009; Klepper, 1996; 2002). Regarding medium-term dynamics, depending on the relationship between market success and innovative activities/successes, one can distinguish a reinforcing interaction leading to a success-breeds-success and monopolistic pattern meanwhile retarding relationships that allow turbulence in market shares and continuous leapfrogging in technological leadership. These results complement empirical regularities like persistent technological or economic performance differences in the former case, and market turbulences with high entry and exit rates in the latter case. Technological spillovers affect such patterns by smoothing turbulences and slowing down the tendency toward monopolization, whereas strong conditions of appropriability reinforce those dynamics.

Industry life-cycle features Recent work on the industry life cycle (ILC) shows how, for narrowly defined markets or sectors (e.g. automobile, tire, laser, TV, penicillin), the mechanisms present in the previous sections interact and shape the pattern of industrial dynamics over a longer period of time. The life cycle starts with an entrepreneurial phase. The high intensity of competition over time may lead to the establishment of a technological standard or dominant design. This process is often accompanied by a sharp shakeout of firms that do not successfully help to establish that standard or fail to adapt to it. Moreover, this standard serves as a major barrier to further entry. The industry then develops into the phase of a routinized regime with less intense competition and stability of market shares.

This development is driven by a change in the major orientation of innovation activities. The process of standardization usually exhausts this phase of product competition, and innovation activities become more process oriented. The long-run pattern of the ILC suggests a succession of industrial structures. Among the main driving forces behind this development are the knowledge and competencies of firms in that sector. Klepper and Simons (2000, 2005), as well as Cantner et al. (2007, 2009, 2010) look at the importance of various knowledge components for ILC development. They distinguish between knowledge acquired by firms before they entered an industry, while being active in that industry, and knowledge related to innovative activities. The time of entry is also considered in relation to knowledge accumulation in the industry. Pre-entry experience, early entrance (and thus high post-entry experience), and degree of innovativeness turned out to be the most important factors for firm survival. Looking at the relative importance of those knowledge categories for survival, it turns out that the disadvantage of lower accumulated knowledge because of a late date of entry can be compensated by innovation knowledge.

The systemic view Another dimension of firm-heterogeneity-based differences in knowledge and competencies is the deliberate exchange of technological know-how (Allen, 1983). Especially in the case of complex technologies, which are based on a larger number of knowledge components and competencies, the exchange of know-how and the cooperation of firms in developing innovations are vital. This cooperative element of innovative activities is at the core of so-called sectoral systems of innovation (Malerba, 2004) in such sectors as automobiles and pharmaceuticals. Large and small firms cooperate and a specific division of labor is agreed upon. This obviously shapes the structure of an industry, often with large core firms and small 'satellite' firms.

DEMAND AND INDUSTRIAL DYNAMICS

In the previous section, we discussed the evolution of technology and markets from a firm perspective. The ability of firms to respond strategically to external stimuli, as well as their attempts to change the competitive environment, is the central force shaping the dynamics of industries and economies. In this section, we deal with the complementary role of users and consumers both in designing markets and in pulling innovations.

The role of demand in innovation processes is explicitly discussed by Adam Smith: the extent of a market limits the division of labor, which in Adam Smith's view is the main trigger for increasing returns leading to new product and process innovations. Indeed,

> this great increase of the quantity of work which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances; . . . and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many. (Smith, 1776, ch. 3)

However, the division of labor is limited by the extent of the market, because

> when the market is very small, no person can have any encouragement to dedicate himself entirely to one employment, for want of the power to exchange all that surplus part of the produce of his own labour, which is over and above his own consumption, for such parts of the produce of other men's labour as he has occasion for. (Ibid.)

The role of increasing returns in the economic process is analyzed by Young (1928), although mainly in heterodox approaches to economics of innovation (Dosi, 1988). By contrast, the explicit tie connecting market size and innovation made by Adam Smith is rarely discussed. A notable exception is the work by the sociologist of invention, Gilfillan (1935a), who not only revisits the ideas of Smith, but also suggests an additional role played by the demand side in the innovation process.

On the one hand, Gilfillan (1935a) suggested that the pace of technology should be faster in those sectors in which the number of potential adopters, and thus firms' incentives to innovate, are higher. On the other, based on a vast qualitative analysis on the shipping industry, he suggests that demand not only provides incentives, but also draws attention to new needs to be addressed by the supply side. In his words, 'there exists a technological lag, a chronic tendency of technology to lag behind demand,' (Gilfillan, 1935b, p. 1); thus only users and consumers can reveal to firms the route to go to satisfy their needs.

These two mechanisms linking demand and innovation, that is, demand as incentive and demand as source of information, can be identified in the literature along two distinct but similar paths: at first, they flourish both in academia and among policy-makers, but they eventually run into diminishing returns when facing incontestable empirical rejections and critics. In the first stage, the solid critiques confronted jeopardize the idea of demand as a determinant of innovation, but ultimately the critiques suggest and compel a sound refinement to the theory. As these two streams of literature are identified and subsequently traced, note that the incentive mechanism is consistent with a mainstream approach where technological choice is driven by market incentives. By contrast, the latter strongly departs from neoclassical economics by disregarding information flow as a relevant problem, but rather considering information as a quasi-public good reproducible at zero marginal cost.

Schmookler (1962, 1966) empirically tested the 'demand-pull' hypothesis, where technological change is pulled by the existence or emergence of new markets because human needs precede technological solutions. He reviews the innovation activity in the railway industry, captured by the numbers of patents, and compares it with the evolution over time of different economic indicators such as stock prices and gross capital formation. He shows that peaks in innovative activities lag behind those capturing the economic performance. Building upon the assumption that economic performance proxies demand as total expenditure, he concludes that 'the influence [upon innovation] of the latter [unfolding economic needs] has been substantial' (Schmookler, 1962, p. 20).

Contemporaneously, Arrow (1962) reveals the mechanism beneath this incentive effect. In the attempt to illustrate the impact of market structure on the propensity to innovate, which we mentioned in the previous section, he analytically states that incentives to innovate are equal to the increase in the mark-up per unit produced by an innovation multiplied by the units sold in the market. The simplicity and the analytical tractability of this proposition make the use of this concept widespread not only in the economic analysis of innovation and technological change (see, among others, Kennedy, 1964; Drandakis and Phelps, 1965; Samuelson, 1965; Hayami and Ruttan, 1970; Acemoglu and Linn, 2005), but also new growth theories (Aghion and Howitt, 1992; Grossman and Helpman, 1991, Romer, 1986, 1990).

Both the Arrow and Schmookler approaches, despite the clarity of the reasoning and their results, run into diminishing returns when confronted with undeniable empirical rejections. Scherer (1982) reruns Schmookler's analysis on a larger data set and rejects the demand-pull hypothesis when using the whole sample. However, when including only capital-goods industries in the analysis, Schmookler's results appear to be valid. Schmookler's hypothesis seems to work only in industries with large firms, facing a stable homogeneous demand, and mainly engaged in incremental product innovations or process innovation.

Overall, the demand-pull hypothesis has an explanatory power of innovation, but the range of its applicability is reduced. Specifically, the main result is that the concept cannot be applied without explicitly referencing the structure of the industry and the joint evolution of the technology side.

Schmookler's approach also fails to explain the dynamic nature of the phenomenon. In Adam Smith's view, the size of the market not only enables innovation, but endogenously generates a further stage where innovation itself expands demand: for instance, that might occur by allowing a lower price or by introducing new products. A further criticism in this direction is that of Kleinknecht and Verspagen (1990), which clearly addresses the problem of endogeneity in technological change; they correct the spurious relationship of innovation and the level of investment by controlling potential latent variables such as sector size. In addition, they test for reverse causality and find evidence of a co-evolution of demand and technology. This is the only paper in economics of innovation that is truly in the spirit of the Smithian increasing returns of demand and technology.

Similarly to Schmookler, Arrow's approach underwent heavy empirical falsification of the mechanism he described. The main result of new growth theory is the prediction of growth with scale effect: if Arrow's incentives mechanism acts as a multiplier, an increase in the market size creates larger incentives and, thus, permanently stimulates growth. Jones (1995) empirically rejects the hypothesis of growth with scale effect on a sample of OECD countries. In conclusion, once the inherent statistical flaws of the early Schmookler analysis are corrected, the magnitude of the demand-pull effect is reduced but the underlying theoretical paradigm still holds.

Young (1998) suggests a possible refinement of the concept, which can explain the lack of scale effect without dismissing the role of demand. He retrieves the 'principle of equivalent solutions' (Gilfillan, 1935b), which states that different innovations fulfilling the same need might coexist. If an economy is large enough and consumers exhibit heterogeneous preferences, firms can find it profitable to investigate alternative solutions to the same technological problem. On the one hand, this dynamic increases variety, thus resulting in higher welfare for users and consumers. On the other hand, it divides the available resources into different streams of R&D (one for each equivalent solution), which reduces the speed of technological improvement, consequently hindering growth. Young (1998) develops a growth model in which rents provided by an increase in the size of the market can be dissipated by developing more than one solution, with the purpose of satisfying a heterogeneous market.

Similarly, Acemoglu and Linn (2005) formalize the same idea and successfully test it empirically using the pharmaceutical market. Foellmi and Zweimüller (2002, 2005) focus on consumers' heterogeneity in terms of income: the more skewed the income distribution, the less homogeneous the final demand, and the weaker the incentives to invent. Ultimately, a large market increases the overall incentive for innovation, but consumer heterogeneity can simultaneously trigger an increase in the variety of alternative solutions, thus hindering growth. Any empirical studies focusing on the relationship between market size and innovation must take into account the mutual crowding-out effect of various equivalent solutions.

Demand as Source of Knowledge

As Gilfillan (1935b) suggests, demand can be interpreted not only as the size of the market providing incentives for invention, but also as a useful source of information to direct research toward the actual needs of potential buyers. The underlying hypothesis of the mechanism is that needs are anticipated in the market, not created by technology. Once again, together with incentives, knowledge is considered as the driving mechanism of the innovative process. Gilfillan's approach has been widely analyzed since the 1960s.

Myers and Marquis (1969) discuss the results of a survey investigating the economic and technological background of 567 innovations in five different industries. They conclude that for about 75 percent of the innovations tested, demand factors were prominent, thus setting an empirical milestone in innovation studies. Indeed, a number of empirical studies followed: Isenson (1969), Rothwell and Freeman (1974), Freeman (1968), Berger (1975), Boyden (1976), Lionetta (1977) and Gilpin (1975). These studies examine the role of demand in anticipating technology and find a tendency of technology to lag behind human needs: 'What is important is what consumers or producers need or want rather than the availability of technological options' (Gilpin, 1975, p. 65).

This paradigm was accepted until the end of the 1970s, when two disruptive articles by Mowery and Rosenberg (1979) and Dosi (1982) tackled its underlying assumptions. These authors explain that the theoretical flaw of those earlier studies was the inability to distinguish demand from the 'limitless set of human needs' (Dosi, 1982, p. 150). For this reason, demand-led studies could simply capture the idea that successfully realized innovations obviously meet some needs, but they could not explain the 'why of certain technological developments instead of others and of a certain timing instead of other' (ibid.). This critique is important because it hits those studies at their core assumption. Since then, innovation studies have mostly focused on the technology side (Freeman, 1994).

However, a few scholars still engage in this research agenda and manage to overcome this critique by refining the conceptualization of the demand side. These researchers try to leave a vague idea of demand by focusing on consumers with very well-defined needs. Teubal (1979), for instance, suggests that the influence of demand upon innovation depends on 'need determinateness, the extent to which preferences are specified (or need satisfaction is expressed) in terms of product classes, functions and features' (Teubal, 1979, cited in Clark, 1985, p. 244).

Von Hippel (1977) introduces the concept of lead users, those users familiar with problems and conditions that the rest of the market will face in the future. An innovator can gain useful insights into users' needs only from these lead users. The stream of literature linked with lead users is flourishing in the managerial literature (Foxall, 1987; von Hippel and Finkelstein, 1979; Parkinson, 1982; Shaw, 1985; Spital, 1978; Voss, 1985; Urban and von Hippel, 1988; Herstatt and von Hippel, 1992; Knodler, 1993; Morrison et al. 2000; Franke and Shah, 2001).

Malerba et al. (2003) develop a model in which a group of users exhibits selective preference for an innovation because they have diverse needs from the rest of the market. Those experimental users allow the creation of a niche market that acts as an incubator for the new technology. In diffusion studies, a similar idea is presented. A new product or process is introduced into the market only if a minimum threshold number of pioneers exists, that is, users with explicit and stringent needs to be fulfilled (Rogers, 1995).

Furthermore, both Windrum and Frenken (2003) and Windrum (2005) highlight the fact that users with diverse preferences can drive innovation cycles in mature industries. Specifically, both show that in some industries, such as the camera and computer industries, the presence of market niches can pull innovation with the purpose of satisfying

particular market niches. Along the same line, Christensen (1997), Adner (2002), and Adner and Levinthal (2001) suggest that disruptive technology can emerge when markets realize that a product can be used in a different way by users with particular needs. They conceive a product as a bundle of characteristics and suggest that, if some characteristics are improved instead of others, a target consumer of a good can be created.

These studies share the perspective that not all users and consumers can provide firms with useful information, but rather only sophisticated consumers or consumers able to specify their needs with high accuracy (Guerzoni, 2007, 2010). In other words, what really matters in the information flow from market to firms is not the limitless set of human desires, but a small subsample of demand consisting of users with well-defined needs.

Thus we can say that the literature on demand and innovation can be divided into two streams. On the one hand, demand can be conceived as the market size and act as an incentive upon firms in order to pull innovation. On the other hand, demand can provide the firm with useful information to direct R&D. Critics of these studies forced both streams to be refined over time: demand might well play a role as incentive, but it should be controlled for its heterogeneity. The role of demand as source of information is also undeniable, but only those consumers well aware of their preferences are able to serve this purpose.

CONCLUSIONS

In the early age of economics, innovation was considered an endogenous factor of growth and development and was, therefore, widely analyzed. Over time, the role of innovation was elminated from the realm of economic studies.

This chapter tracked the efforts of scholars of economic innovation to keep the co-evolution of technology and markets as the key units of analysis to explain the development of industries.

This literature consists of two complementary building blocks. On the one side, the issue can be tackled by highlighting the role of firms and entrepreneurs in actively shaping the competitive environment and reacting to change by introducing product, process and organizational innovation. Conversely, the focus can be set on the demand side, which provides not only incentives, but also relevant information to direct R&D efforts along the right path. This dichotomy is known in the literature as the 'technology push vs. demand pull debate' (Freeman, 1994).

In our chapter, we kept this separation for illustrative purpose only: indeed, once we acknowledge that technology and markets co-evolve, any clear-cut distinction is impossible, as well as any superiority of one effect over the other. A second large divide exists in the literature. One stream of literature reduces the problem of innovation to simply a matter of rewards to innovation. Incentives clearly play a role in defining opportunities and constraints, but they are only one side of the same coin. The other side considers innovation as the end result of a complex process of learning that simultaneously takes place both in the firms and in the consumers. Innovation itself should be conceptualized as the process of matching available technological opportunities with well-defined needs.

Further challenges for the issue rely precisely on improving the understanding of this process by looking at the interaction of the two divides. First, both users' and firms' impact upon innovation should be simultaneously taken into account because of the relevant feedbacks among different actors in the system. Second, and for analogous reasons, the big divide between incentive-based and knowledge-based approaches must be bridged. Indeed, the degree of availability of knowledge heavily impinges upon the distribution of expected profit. Alternatively, it is partly endogenously determined by incentives to invest in codification, knowledge transfer and absorptive capabilities.

REFERENCES

Acemoglu, Daron and Joshua Linn (2005), 'Market size in innovation: theory and evidence from the pharmaceutical industry', *Quarterly Journal of Economics*, **119**, 1049–90.

Adner, Rod (2002), 'When are technologies disruptive? A demand-based view of the emergence of competition', *Strategic Management Journal*, **23**, 667–88.

Adner, Rod and Daniel Levinthal (2001), 'Demand heterogeneity and technology evolution: implications for product and process innovation', *Management Science*, **47**, 611–28.

Aghion, Philippe and Peter Howitt (1992), 'A model of growth through creative destruction', *Econometrica*, **60**, 323–51.

Allen, R.C. (1983), 'Collective invention', *Journal of Economic Behaviour and Organisation*, **4**, 1–24.

Arrow, Kenneth J. (1962), 'Economic welfare and the allocation of resources for invention', in Richard R. Nelson (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, National Bureau of Economic Research, Conference Series, Princeton, NJ: Princeton University Press, pp. 609–25.

Arrow, K.J. (1991), 'The dynamics of technological change', in OECD (ed.), *Technology and Productivity: The Challenge for Economic Policy*, Paris, OECD, pp. 473–6.

Audretsch, D.B. (1995), 'Innovation, growth and survival', *International Journal of Industrial Organization*, **13** (4), 441–57.

Auerswald, P.E. (2010), 'Entry and Schumpeterian profits: how technological complexity affects industry evolution', *Journal of Evolutionary Economics*, **20** (4), 553–82.

Babbage, C. (1832), *On the Economy of Machinery and Manufactures*, Teddington: Echo Library.

Barzel, Y. (1968), 'Optimal timing of innovations', *Review of Economics and Statistics*, **50**, 348–55.

Beath J., Y. Katsoulacos and D. Ulph (1989), 'The game-theoretic analysis of innovation: a survey', *Bulletin of Economic Research*, **41** (3), 164–84.

Berger, Alan J. (1975), 'Factors influencing the locus of innovation activity leading to scientific instrument and plastics innovation', SM thesis, Cambridge, MA: Sloan School of Management, MIT.

Bottazzi G. and A. Secchi (2006), 'Gibrat's law and diversification', *Industrial and Corporate Change*, **15** (5), 847–75.

Boyden, Julian W. (1976), 'A study of the innovative process in the plastics additives industry', SM thesis, Cambridge, MA: Sloan School of Management, MIT.

Cantner, U. and J.J. Krüger (2004), 'Geroski's stylized facts and mobility in large German manufacturing firms', *International Journal of Industrial Organisation*, **24** (3), 267–83.

Cantner, U., K. Dressler and J. Krüger (2007), 'Die Evolution der deutschen Automobilindustrie (1886–1939) – Die Rolle technologischen Wissens und seiner Anwendung', in R. Walter (ed.), *Innovationsgeschichte*, Stuttgart: Franz Steiner Verlag, pp. 333–52.

Cantner, U., J. Krüger and K. von Rhein (2009), 'Knowledge and creative destruction over the industry life cycle – the case of the German automobile industry', *Economica*, **76** (301), 132–48.

Cantner, U., J. Krüger and K. von Rhein (2010), 'Knowledge compensation in the German automobile industry', *Applied Economics*, doi: 10.1080/00036840902762738.

Cantwell, J. (1993), 'Technological competence and evolving patterns of international production', in H. Cox, J. Clegg and G. Ietto-Giles (eds), *The Growth of Global Business*, London: Routledge, pp. 19–37.

Caves, R.E. and D.R. Barton (1990), *Efficiency in U.S. Manufacturing Industries*, Cambridge, MA: MIT Press.

Cefis, E. M. Ciccarelli and L. Orsenigo (2007), 'Testing Gibrat's legacy: a Bayesian approach to study the growth of firms', *Structural Change and Economic Dynamics*, **18**, 348–69.

Christensen, Clayton M. (1997), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Cambridge, MA: Harvard Business School Press.

Clark, Kim (1985), 'The interaction of design hierarchies and market concepts in technological evolution', *Research Policy*, **14**, 235–51.

Cohen, W.M. and D. Levinthal (1989), 'Innovation and learning: the two faces of R&D', *Economic Journal*, **99** (397), 569–96.

Cowan, R., P.A. David and D. Foray (2000), 'The explicit economics of knowledge: codification and tacitness', *Industrial and Corporate Change*, **9** (2), 211–53.

Cyert, R.M. and J.G. March (1963), *A Behavioural Theory of the Firm*, Englewood Cliffs, NJ: Prentice-Hall.

Dasgupta, P. (1986), 'The theory of technological competition', in J.E. Stiglitz and F. Mathewson (eds), *New Developments in the Analysis of Market Structure*, London and Cambridge, MA: Macmillan, pp. 519–47.

Dasgupta, P. and J.E. Stiglitz (1980a), 'Industrial structure and the nature of innovative activity', *Economic Journal*, **90**, 266–93.

Dasgupta, P. and J.E. Stiglitz (1980b), 'Uncertainty, industrial structure and the speed of R&D', *Bell Journal of Economics*, **11**, 1–28.

D'Aspremont, C. and A. Jacquemin (1988), 'Cooperative and noncooperative R&D in duopoly with spillovers', *American Economic Review*, **78**, 1133–7.

Demsetz, H. (1969), 'Information and efficiency: another viewpoint', *Journal of Law and Economics*, **12**, 1–22.

Doms, M., T. Dunne and M.J. Roberts (1995), 'The role of technology use in the survival and growth of manufacturing plants', *International Journal of Industrial Organization*, **13** (4), 523–42.

Dopfer, K., J. Foster and J. Potts (2004), 'Micro-meso-macro', Schumpeter Conference, Milan 2004.

Dosi, Giovanni (1982), 'Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change', *Research Policy*, **11**, 147–62.

Dosi, G. (1988), 'The nature of the innovative process', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds) (1988), *Technical Change and Economic Theory*, London: Pinter Publishers, pp. 221–38.

Dosi, G. (2001), *Innovation, Organization and Economic Dynamics: Selected Essays*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Dosi, G., O. Marsili, L. Orsenigo and R. Salvatore (1995), 'Learning, market selection and the evolution of industrial structures', *Small Business Economics*, **7** (6), 411–36.

Drandakis, Emmanuel M. and Edmond S. Phelps (1965), 'A model of induced invention, growth and distribution', *Economic Journal*, **76**, 823–40.

Ericson, R. and A. Pakes (1995), 'Markov perfect industry dynamics: a framework for empirical work', *Review of Economic Studies*, **62**, 53–82.

Foellmi, Reto and Josef Zweimüller (2002), 'Heterogeneous Mark-ups, Demand Composition, and the Inequality–Growth Relation', Royal Economic Society Annual Conference 76, London, UK: Royal Economic Society.

Foellmi, Reto and Josef Zweimüller (2005), 'Income distribution and demand-induced innovations', CEPR Discussion Paper 4985.

Foxall, Gordon R. (1987), 'Strategic implications of user-initiated innovation', in R. Rothwell and J. Bessant (eds.), *Innovation: Adaptation and Growth*, Amsterdam: Elsevier, pp. 25–36.

Franke, Nikolaus and Sonali Shah (2001), 'How communities support innovative activities: an exploration of assistance and sharing among end-users', MIT Sloan School of Management Working Paper no. 4164.

Freeman, Chris (1968), 'Chemical process plant: innovation and the world market', *National Institute Economic Review*, **45**, 29–57.

Freeman, Chris (1994), 'The economics of technical change', *Cambridge Journal of Economics*, **18**, 479–82.

Geroski, P.A. (1995), 'What do we know about entry?', *International Journal of Industrial Organization*, **13** (4), 421–40.

Gilbert, R.J. and D.M.G. Newberry (1982), 'Preemptive patenting and the persistence of monopoly', *American Economic Review*, **72**, 514–26.

Gilfillan, Seabury C. (1935a), *The Sociology of Invention*, Chicago, IL: Follett Publishing Company.

Gilfillan, Seabury C. (1935b), *Inventing the Ship*, Chicago, IL: Follett Publishing Company.

Gilpin, Robert (1975), *Technology, Economic Growth and International Competitiveness*, study prepared for the Subcommittee on Economic Growth of the Congressional Joint Economic Committee, Washington, DC: US Government Printing Office.

Grossman, Gene and Elhanan Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press.

Guerzoni, M. (2007), 'Size and sophistication: the two faces of demand', CESPRI Working Papers no. 197, Università Bocconi, Milan, Italy.

Guerzoni, M. (2010), 'The impact of market size and users' sophistication on innovation: the patterns of demand and the technology life cycle', *Economic of Innovation and New Technology*, forthcoming.

Hayami, Yujiro and Vernon W. Ruttan (1970), 'Factor prices and technical change in agricultural development: the U.S. and Japan, 1880–1960', *Journal of Political Economy*, **77**, 1115–41.

Herstatt, Cornelius and Eric von Hippel (1992), 'From experience: developing new product concepts via the lead user method: a case study in low tech field', *Journal of Product Innovation Management*, **9**, 23–221.

Isenson, R.S. (1969), 'Project Hindsight: an empirical study of the sources of ideas utilized in operational

weapon systems', in William H. Gruber and Donald G. Marquis (eds), *Factors in the Transfer of Technology*, Cambridge, MA: MIT Press, pp. 155–76.
Ijiri, Y. and H. Simon (1977), *Skewed Distributions and the Size of Business Firms*, Amsterdam: North Holland.
Jones, Charles I. (1995), 'R&D-based models of economic growth', *Journal of Political Economy*, **103**, 759–84.
Jovanovic, B. (1982), 'Selection and the evolution of industry', *Econometrica*, **50** (3), 649–70.
Kamien, M. and N. Schwartz (1980), *Market Structure and Innovation*, Cambridge: Cambridge University Press.
Katz, M.L. and C. Shapiro (1985), On the Licensing of Innovations, Rand Journal of Economics 16, 1985, 504–20.
Kennedy, Charles (1964), 'Induced bias in innovation and the theory of distribution', *Economic Journal*, **74**, 541–7.
Kleinknecht, Alfred and Bart Verspagen (1990), 'Demand and innovation: Schmookler re-examined', *Research Policy*, **19**, 387–94.
Klepper, S. (1996), 'Entry, exit, growth and innovation over the product life cycle', *American Economic Review*, **86**, 562–83.
Klepper, S. (2002), 'Firm survival and the evolution of oligopoly', *RAND Journal of Economics*, **33** (1), 37–61.
Klepper, S. and K.L. Simons (2000), 'The making of an oligopoly: firm survival and technological change in the evolution of the U.S. tire industry', Journal of Political Economy, **108** (4), 728–60.
Klepper, S. and K.L. Simons (2005), 'Industry shakeouts and technological change', *International Journal of Industrial Organization*, **23** (1–2), 23–43.
Knight, F.H. (1921), *Risk, Uncertainty and Profit*, New York: Kelley.
Knodler, Janet T. (1993) 'Early examples of user-based industrial research', *Business and Economic History*, **22**, 285–94.
Levin, R.C., W.M. Cohen and D.C. Mowery (1985), 'R&D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses', *The American Economic Review*, **75** (2), 20–24.
Levin, R.C. and P.C. Reiss (1984), 'Tests of a Schumpeterian model of R&D and market structure', in Z Griliches (ed.), *R&D, Patents, and Productivity*, Chicago, IL and London: University of Chicago Press, pp. 175–204.
Lionetta, William G. (1977), 'Sources of innovation within the pultrusion industry', unpublished S.M. thesis, Sloan School of Management, Cambridge, MA: MIT.
Malerba, F. (2004), 'Sectoral systems of innovation: basic concepts', in F. Malerba (ed.), *Sectoral Systems of Innovation: Concepts, Issues and Analysis of Six Major Sectors in Europe*, Cambridge: Cambridge University Press, pp. 9–35.
Malerba, F., R. Nelson, L. Orsenigo and S. Winter (1999), 'History friendly models of industrial evolution: the computer industry', *Industrial and Corporate Change*, **1**, 3–41.
Malerba, F. and L. Orsenigo (1995), 'Schumpeterian patterns of innovation', *Cambridge Journal of Economics*, **19**, 47–65.
Malerba, F. and L. Orsenigo (1996), 'The dynamics and evolution of industries', *Industrial and Corporate Change*, **5** (1), 51–87.
Malerba, F. and L. Orsenigo (1997), 'Technological regimes and sectoral patterns of innovative activities', *Industrial and Corporate Change*, **6**, 83–117.
Malerba, F. and L. Orsenigo (2000), 'Knowledge, innovation activities and industrial evolution', *Industrial and Corporate Change*, **9** (2), 289–313.
Malerba, F. and L. Orsenigo (2002), 'Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: towards a history friendly model', *Industrial and Corporate Change*, **11 (4)**, 667–703.
Malerba, F., R. Nelson and L. Orsenigo (2003), 'Demand, innovation and the dynamics of market structure: the role of experimental users and diverse preferences; KITeS Working Paper, Milan.
Mazzucato, M. and W. Semmler (1999), 'Market share instability and stock price volatility during the industry life-cycle: the US automobile industry', *Journal of Evolutionary Economics*, **9** (1), 67–96.
Metcalfe, S. (1994), 'Competition, Fisher's principle and increasing returns to selection', *Journal of Evolutionary Economics*, **4**, 327–46.
Metcalfe, S. (1998), *Evolutionary Economics And Creative Destruction*, London: Routledge.
Morrison, Pamela D., John H. Roberts and Eric von Hippel (2000), 'Determinants of user innovation and innovation sharing in a local market', *Management Science*, **46**, 1513–27.
Mowery, D., R. Nelson, B. Sampat and A. Ziedonis (2004), *Ivory Tower and Industrial Innovation: Technology Transfer Before and After Bayh–Dole*, Stanford, CA: Stanford University Press.
Mowery, David C. and Nathan Rosenberg (1979), 'The influence of market demand upon innovation: a critical review of some recent empirical studies', *Research Policies* **8**, 102–53.
Mueller D. and J.R. Cable (2008), 'Testing for persistence of profits' differences across firms', *International Journal of the Economics of Business*, **15** (2), 201–28.

Myers, Summer and Donald G. Marquis (1969), *Successful Industrial Innovation*, Washington, DC: National Science Foundation.
Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA: Harvard University Press.
Nelson, R.R. (1991), 'Why do firms differ, and how does it matter?', *Strategic Management Journal*, **12**, Special Issue: Fundamental Research Issues in Strategy and Economics, 61–74.
Parkinson, S.T. (1982), 'The role of the user in successful new product development', *R & D Management*, **12**, 123–31.
Pavitt, K. (1984), 'Sectoral patterns of technical change: towards a taxonomy and a theory', *Research Policy*, **13**, 343–73.
Penrose, E. (1959), *The Theory of the Growth of the Firm*, London: Basil Blackwell.
Phillips, A. (1971), *Technology and Market Structure: A Study of the Aircraft Industry*, Lexington, MA: Heath, Lexington Books.
Polanyi, M. (1967), *The Tacit Dimension*, New York: Anchor Books.
Reinganum, J.F. (1985), 'Innovation and industry evolution', *Quarterly Journal of Economics*, **100**, 81–99.
Reinganum, J.F. (1989), 'The timing of innovation: research, development, and diffusion', in R. Schmalensee and R.D. Willig (eds), *Handbook of Industrial Organization*, Volume I, Elsevier Science Publishers, pp. 849–908.
Rogers, Everett (1995), *Diffusion of Innovations*, 4th edu, New York: The Free Press.
Romer, Paul M. (1986), 'Increasing returns and long-run growth', *Journal of Political Economy*, **94**, 1002–37.
Romer, Paul M. (1990), 'Endogenous technological change', *Journal of Political Economy*, **98**, 71–102.
Rosenberg, N. (1976), Perspectives on Technology, Cambridge: Cambridge University Press.
Rosenberg, N. and R. Nelson (1994), 'American universities and technical advance in industry', *Research Policy*, **23** (3), 323–48.
Rothwell, Roy and Chris Freeman (1974), 'SAPPHO updated – Project SAPPHO Phase II', *Research Policy* **3**, 258–91.
Sah, R.K. and J.E. Stiglitz (1987), 'The invariance of market innovation to the number of firms', *Rand Journal of Economics*, **18**, 98–108.
Samuelson, Paul (1965), 'A theory of induced innovations along Kennedy–Weisacker lines', *Review of Economics and Statistics*, **47**, 444–64.
Saviotti, P. (1996), *Technological Evolution, Variety and the Economy*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.
Scherer, F.M. (1967), 'Research and development resource allocation under rivalry', *Quarterly Journal of Economics*, **81**, 359–94.
Scherer, F.M. (1982), 'Demand pull and technological invention: Schmookler revisited', *Journal of Industrial Economics*, **30**, 225–37.
Schmookler, Jakob (1962), 'Economic sources of inventive activity', *Journal of Economic History*, **22** (1), 1–20.
Schmookler, Jakob (1966), *Invention and Economic Growth*, Cambridge, MA: Harvard University Press.
Schumpeter, J. (1942/1950), *Capitalism, Socialism and Democracy*, New York: Harper Brothers.
Schumpeter, J.A. (1935/1912), *Theorie der Wirtschaftlichen Entwicklung*, Berlin: Duncker & Humblot, 5.Auflage, 1935.
Schumpeter, Joseph A. (1943), *Capitalism, Socialism and Democracy*, London: George Allen & Unwin.
Shaw, Brian (1985), 'The role of the interaction between the user and the manufacturer in medical equipment innovation', *R&D Management*, **15**, 283–92.
Simon, H.A. (1955), 'A behavioural model of rational choice', *Econometrics*, **19**, 99–118.
Smith, A. (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations*, London: W. Strahan and T. Cadell.
Spence, M. (1984), 'Cost reduction, competition, and industry performance', *Econometrica*, **52**, 101–21.
Spital, Clifford F. (1978), *The Role of the Manufacturer in the Innovation Process for Analytical Instruments*, PhD diss., Sloan School of Management, MIT, Cambridge, MA.
Sutton, J. (1998), *Technology and Market Structure: Theory and History*, Cambridge, MA: MIT Press.
Teece, D.J. (1988), 'Technological change and the nature of the firm', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*, New York: Pinter, pp. 256–81.
Teubal, Morris (1979), 'On user needs and need determination: aspects of the theory of technological innovation', in Michael J. Baker (ed.) *Industrial Innovation: Technology, Policy, Diffusion*, London: Macmillan.
Urban, Glen and Eric von Hippel (1988), 'Lead user analysis for the development of new industrial products', *Management Science*, **34**, 569–82.
Verspagen, B. (1992), *Uneven Growth between Interdependent Economies*, Maastricht: UPM.
Von Hippel, Eric (1977), 'Transferring process equipment innovations from user-innovators to equipment manufacturing firms', *R&D Management* **8**, 13–22.

Von Hippel, Eric and Stan N. Finkelstein (1979), 'Analysis of innovation in automated clinical chemistry analyzers', *Science & Public Policy*, **6**, 24–37.
Voss, Christopher A. (1985), 'The role of users in the development of applications software', *Journal of Product Innovation Management*, **2**, 113–21.
Wernerfelt, B. (1984), 'A resource-based view of the firm', *Strategic Management Journal*, **5**, 171–80.
Windrum, Paul (2005), 'Heterogeneous preferences and new innovation cycles in mature industries: the amateur camera industry 1955–1974', *Industrial and Corporate Change*, **14**, 1043–74.
Windrum, Paul and Koen Frenken (2003), 'Successive cycles of innovation: the importance of user heterogeneity and design complementarities for radical product innovations in the camera and computer industries', paper presented at the SPRU conference 'What do we know about innovation?', University of Sussex, 13–15 November.
Witt, U. (1987), *Individualistische Grundlagen der evolutorischen Ökonomik*, Tübingen: J.C.B. Mohr (Paul Siebeck).
Young, A. (1928), 'Increasing returns and economic progress', *Economic Journal*, **38**, 529.
Young, A. (1998), 'Growth without scale effect', *Journal of Political Economy*, **106**, 41–3.
Zucker, L.G., M.R. Darby and M.B. Brewer (1998), 'Intellectual human capital and the birth of U.S. biotechnology enterprises', *American Economic Review*, **88** (1), 290–306.

25 How do young innovative companies innovate?

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INTRODUCTION

Both the scientific community and policy-makers are showing increasing interest in the role that young innovative companies (YICs) play in the new technology implementation process, as these ultimately contribute to the renewal of the industrial structure and to aggregate economic growth.[1] For instance, one possible explanation of the transatlantic productivity gap could be found in the revealed capacity of the US economy to generate an increasing number of young innovative firms that manage to survive and introduce new products at the core of emerging sectors. On the contrary, young European firms reveal lower innovative capacity and most are doomed to early failure, the process resulting in churning rather than in innovative industrial dynamics (see Bartelsman et al., 2004; Santarelli and Vivarelli, 2007).

There are several different sources of innovation at the firm level; together with in-house and external R&D activities, technological acquisition (TA) in its embodied (machinery and equipment) and disembodied forms must be taken into account. This input–output framework can be seen as an extension of the 'knowledge production function' (KPF, initially put forward by Griliches, 1979), a tool for describing the transformation process running from innovative inputs to innovative outputs.

While most previous microeconometric research focuses on the R&D–Innovation–Productivity chain (see next section), few studies explicitly discuss the role of TA and the possible differences in the KPF across firms of different ages. By using microdata from the European Community Innovation Survey 3 (CIS 3) for the Italian manufacturing sector, the main novelty of this chapter lies in the authors' investigation of whether R&D and TA lead to significant differences in determining innovative output in firms of different ages. In particular, it will be tested whether the KPF of YICs exhibits some peculiarities in comparison with the KPF of mature incumbent firms.

The remainder of the chapter is organized as follows: a discussion of the theoretical framework on which this work is based is followed by a description of the data and indicators used in the empirical analysis and by discussion of the adopted econometric methodology. Subsequently, the empirical outcomes derived from the descriptive analysis and the econometric estimates are discussed. The fifth section concludes the chapter by briefly summarizing the main findings.