Volume Title: The Rate and Direction of Inventive Activity Revisited

Volume Author/Editor: Josh Lerner and Scott Stern, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-47303-1; 978-0-226-47303-1 (cloth)

Volume URL: http://www.nber.org/books/lern11-1

Conference Date: September 30 - October 2, 2010

Publication Date: March 2012

Chapter Title: How Entrepreneurs Affect the Rate and Direction of Inventive Activity

Chapter Authors: Daniel F. Spulber

Chapter URL: http://www.nber.org/chapters/c12356

Chapter pages in book: (p. 277 - 315)

5

How Entrepreneurs Affect the Rate and Direction of Inventive Activity

Daniel F. Spulber

5.1 Introduction

Why does innovative entrepreneurship occur in established industries? Entrepreneurship entails costs of setting up firms and entering markets. Entrepreneurial entry also involves competing with existing firms, which dissipates economic rents and can destroy existing firms. In contrast, innovators can transfer technology to existing firms taking advantage of incumbents' assets and avoiding the costs of entrepreneurship and competition. Creative destruction therefore gives innovators and existing firms incentives to cooperate through technology transfer. Yet, innovative entrepreneurship in established industries is an important phenomenon that generates technological change, investment, employment, and economic growth. Understanding creative destruction poses a challenge to researchers, business practitioners, and public policymakers.

To examine creative destruction, I present a strategic innovation model that examines how innovators and incumbent firms choose between cooperation and competition. I show how multidimensional innovation—Schumpeter's "new combinations"—helps to explain the phenomenon of innovative entrepreneurship. I show how the transferability of product and process

Daniel F. Spulber is the Elinor Hobbs Distinguished Professor of International Business and professor of management strategy at the Kellogg School of Management, Northwestern University, and professor of law (courtesy) at Northwestern University Law School.

I gratefully acknowledge the support of a research grant from the Ewing Marion Kauffman Foundation. I thank Ken Arrow, Joshua Gans, Shane Greenstein, Josh Lerner, Bob Litan, Scott Stern, and Bob Strom for their very helpful comments. I also thank my discussant Luis Cabral for his very useful and constructive suggestions. I also thank participants at the NBER Rate and Direction of Inventive Activity 50th Anniversary conferences for their stimulating discussions.

innovations affects the mix of entrepreneurship and contracting. Innovators affect the rate and direction of inventive activity either by transferring technology to existing firms or by embodying new technology in new firms. The resulting market outcomes determine what types of firms innovate and how product and process inventions are commercialized.

I introduce a model in which inventions are multidimensional, consisting of both a new product design and a new process invention. Innovators encounter difficulties in either partial or full transfers of technology. Entrepreneurs enter the market with both a horizontally differentiated product and lower production costs. The key insight of the analysis is that product differentiation offsets the creative destruction that results from more efficient production. This generates the following main results. First, when only process innovations are transferable, greater product differentiation tends to generate entrepreneurship, helping to address the challenge of entrepreneurship. Incremental innovations tend to favor entrepreneurship, and significant innovations favor technology transfer. Greater product differentiation gives innovators greater incentives to invent than existing firms because of the incremental returns that innovators can obtain from entrepreneurship. Second, when only product design innovations are transferable, entrepreneurial entry occurs if products are sufficiently differentiated or if the production process innovation is significant. In that situation, the innovator's incentive to invent is again greater than that of an incumbent monopolist.

Third, I extend the strategic game by introducing an independent inventor with a process invention who interacts with an established firm and an independent entrepreneur. The inventor offers the new technology to the established firm and the potential entrepreneur, who in turn play a strategic technology adoption game. In the second stage, the product market outcome can consist of continued monopoly by the established firm or differentiated-products competition between the established firm and the entrepreneurial entrant. The incumbent firm's inertia, first noted by Arrow (1962), has an important new implication. The royalty that induces adoption by the incumbent firm also will induce adoption by an entrepreneurial entrant. The inventor thus will sell either to the entrepreneur or to both the entrepreneur and the incumbent firm. This means that in either situation, the inventor will transfer the process technology to an entrepreneur. This provides another answer to the challenge of entrepreneurship: Due to strategic interaction, independent inventors who do not have the option of entrepreneurship tend to license their technologies to both entrepreneurs and existing firms.

The principal contribution of the analysis is to consider product differentiation in the competition between the innovative entrant and the established firm. Sufficient product differentiation implies that industry profits can be greater than the profits of the incumbent monopolist. This contrasts with related work by Gans, Hsu, and Stern (2000), Gans and Stern (2000, 2003), and Spulber (2011). Gans and Stern (2000), for example, study an

R&D race where the winner can license the technology and faces the possibility of imitation; see also Salant (1984), Katz and Shapiro (1987), and Reinganum (1981, 1982, 1989). Gans and Stern (2000) assume that industry profits after entrepreneurial entry are less than the profits of the incumbent monopolist with the new technology, and as a result, entrepreneurial entry does not occur in equilibrium. Gans and Stern (2000) suggest that entry by a startup is "something of an economic puzzle" in the absence of noncontractible information asymmetries. Spulber (2011) considers creative destruction when the entrepreneurial entrant displaces the incumbent through Bertrand competition. It is useful to observe that standard analyses of innovation also assume homogeneous products and find that due to the effects of competition, the monopolist has a greater incentive to invent than does an entrant; see Gilbert and Newbery (1982) and Gilbert (2006). The standard assumption of homogeneous products implies that an incumbent monopolist has profits that are greater than those of the entire industry after entry. This condition is referred to as the "persistence of monopoly" and the "efficiency condition."[1] Also, in Anton and Yao's (2003) study of imitation and technology transfer, the imitative firm and the innovator are Cournot duopolists with homogeneous products.

In practice, the entry of innovative entrepreneurs demonstrates that many innovators chose to become entrepreneurs rather than to transfer their technologies to existing firms. Despite the apparent advantages of established firms, entrepreneurs have been recognized as major contributors to innovation at least since Jean-Baptiste Say (1841, 1852). Entrepreneurship is one of the main forms of commercialization of invention; see Baumol (1968, 1993, 2002, 2006), Audretsch (1995a, 1995b), Audretsch, Keilbach, and Lehmann (2006), Acs et al. (2004), Schramm (2006), and Baumol, Litan, and Schramm (2007). Schumpeter emphasizes that entrepreneurs provide a large share of the technological innovations that stimulate the growth and development of capitalist economies. Schumpeter (1934, 66) observes that "new combinations are, as a rule, embodied, as it were, in new firms which generally do not arise out of the old ones but start producing beside them." Entrepreneurs transform the economy through "gales of creative destruction," creating new firms that displace existing firms through competition. Our analysis shows why new combinations are embodied in new firms. Entrepreneurs play an important role in the economy by establishing firms that in turn create markets and organizations; see Spulber (2009). In newly established industries, entrepreneurs often flood the market applying widely different approaches and technologies, rather than relying on the initial entrants.

1. Chen and Schwartz (2009) consider vertical product differentiation where the dominant firm produces multiple goods and find that competition can yield greater returns than monopoly (see also Greenstein and Ramey 1998). This differs from my analysis in which the incumbent firm and the entrant compete on equal terms. They do not consider the question of innovation and entrepreneurship.

The chapter is organized as follows. Section 5.2 examines empirical studies of innovative entrepreneurship and technology transfer. Section 5.3 presents the game of strategic innovation played by an innovator and an incumbent firm. Section 5.4 characterizes the equilibrium outcome of the strategic innovation game. Section 5.5 considers an adoption-and-entry game with an independent innovator who chooses whether to transfer the technology to an incumbent firm, to an entrepreneur, or to both. Section 5.6 concludes the discussion.

5.2 Technology Transfer versus Entrepreneurship

There are several major modes of innovation. First, independent innovators can transfer technology by sale or licensing to existing firms or to independent entrepreneurs. Second, entrepreneurs innovate by establishing new firms that embody new products, manufacturing processes, transaction systems, and business methods. Third, existing firms can innovate by commercializing products and processes developed through their internal research and development (R&D) laboratories, collaboration with R&D partners, licensing of new technologies, and acquisition of start-ups. Innovation involves realizing new business opportunities and need not depend on scientific discoveries, as Schumpeter (1964) points out.

The theoretical analysis in the later sections examines the interaction between an innovator and an established firm, and possibly between an innovator and an independent entrepreneur. The model is designed to study the basics of cooperation and competition. In practice, there can be many innovators and incumbent firms. The problem is sufficiently complex that cross-industry studies may be needed to identify the interactive effects of product differentiation and production technologies. This section provides some industry comparisons, although additional research is needed to make these comparisons in a more systematic manner.

5.2.1 The Choice between Entrepreneurial Entry and Technology Transfers

Interaction between independent innovators and existing firms is an important determinant of the mode of innovation. Innovators and existing firms weigh the costs and benefits of transferring technology against the costs and benefits of entrepreneurial entry. Innovators may be independent inventors, scientists and engineers employed by universities and research laboratories, or specialized technology firms.

Studies of academic scientists and engineers illustrate the basic choice between entrepreneurial entry and technology transfer. These innovators engage in both entrepreneurship and technology transfers. There have been hundreds of entrepreneurial firms that are spinoffs from universities; see O’Shea et al. (2005) and the references therein. Lowe and Ziedonis (2006) consider a sample of 732 inventions at the University of California that were licensed exclusively to a firm. They distinguish between licensing to entrepreneurs and licensing to existing firms, and find that start-up firms licensed 36 percent of the inventions and existing firms licensed the remainder. The study implicitly provides evidence of the choice between licensing to a start-up and licensing to an incumbent because over 75 percent of inventions licensed to start-ups were initially reviewed by established firms that sponsored the research or through nondisclosure agreements with the opportunity to license.

Innovators in biotech who are associated with universities establish new firms or attract firms seeking technology transfers; see Prevezer (1997) and Audretsch (2001). Zucker, Darby, and Armstrong (1998) distinguish between biotech firms that are entrepreneurial entrants and those that are incumbents and consider both ownership and contractual technology transfers:

> Our telephone survey of California star scientists found that academic stars may simultaneously be linked to specific firms in a number of different ways: exclusive direct employment (often as CEO or other principal), full or part ownership, exclusive and nonexclusive consulting contracts (effectively part-time employment), and chairmanship of or membership on scientific advisory boards. (69)

Zucker, Darby, and Brewer (1998) provide indirect evidence of the choice between technology transfer and entrepreneurship, and find "strong evidence that the timing and location of initial usage by both new dedicated biotechnology firms ('entrants') and new biotech subunits of existing firms ('incumbents') are primarily explained by the presence at a particular time and place of scientists who are actively contributing to the basic science as represented by publications reporting genetic-sequence discoveries in academic journals" (290). The presence of both types of firms in the sample is suggestive of the choice between entrepreneurship and technology transfer (511 entrants, 150 incumbents, 90 unclassified), although their study does not identify whether the star scientists commercialized their technology by establishing new firms or by transferring technology to existing firms (Zucker, Darby, and Brewer 1998).

Vohora, Wright, and Lockett (2004) study nine entrepreneurial startups in the UK that were university spinouts (USOs). Academic entrepreneurs and the university examine commercialization options, essentially choosing between technology transfer and entrepreneurship. The academic entrepreneur that established the company Stem Cell attempted to transfer his technology to existing firms that had sponsored his research. He observed that: "Commercial partners and industry were not interested. It was so early stage they thought it was a bit wacky. They all had first option to acquire the patents that had been filed from the sponsored research but did not take any of them up which left the university in an interesting position with a huge patent portfolio to exploit commercially" (Vohora, Wright, and Lockett 2004, 156). Vohora and colleagues (2004, 156) observe that for those academic entrepreneurs who were not able to transfer their technology to others:

> the opportunity was re-framed in order to take account of what the academic had learnt: industry's lack of desire to license or co-develop early stage technologies in this field and a preference instead to market later stage technologies that showed a high probability of generating commercial returns. Instead of selecting licensing or co-development as routes to market, the academic entrepreneur had learnt that the best route to market was to assemble the necessary resources and develop the capabilities required to exploit the IP himself through a USO venture.

Furman and MacGarvie (2009) find that the growth of in-house R&D capabilities in large pharmaceutical firms depended heavily on technology transfer through firm-university collaborations and contract research.

Innovators also can be specialized firms who develop products and processes that are inputs to other firms. These specialized firms face the problem of entrepreneurial entry downstream or technology transfer to downstream firms. In biotech, for example, many innovators were new firms. These start-ups carried out most of the initial stages of applied research in recombinant DNA technology and molecular genetics (Galambos and Sturchio 1998). In the US biotech industry, about 5,000 small and start-up firms provided technology inputs to health care, food and agriculture, industrial processes, and environmental cleanup industries (Audretsch 2001). These biotech firms were themselves innovators who needed to decide how best to commercialize their discoveries. The small biotech firms and major pharmaceutical companies chose between cooperation and competition. The small biotech firms generally have tended to engage in technology transfer to the larger pharmaceutical companies rather than entering the market to produce and sell products based on their discoveries. Technology transfer in biotech occurred through cooperative arrangements: "The large companies exchanged financial support and established organizational capabilities in clinical research, regulatory affairs, manufacturing, and marketing for the smaller firms' technical expertise and/or patents" (Galambos and Sturchio 1998, 252).

Similar patterns of technology transfers were observed in other industries. For example, in the chemical industry, specialized engineering firms (SEFs) are examples of entrepreneurial entrants. These SEFs chose entrepreneurial entry in R&D rather than developing basic technologies for incumbent chemical companies. However, once they were established, these entrepreneurial entrants developed and marketed process technology to large oil companies and chemical companies (Arora and Gambardella 1998). Innovative entrepreneurial entry also took place in the photolithographic alignment equipment industry. Henderson (1993) examines entry of entrepreneurial firms in the period 1960 to 1985. After entry, these firms sold equipment to major semiconductor manufacturers. According to the study, single-product start-ups initially entered the industry, but as incumbent firms become large and diversified, later entrants were firms with experience in related technologies. Existing firms were displaced by later entrants who introduced innovations in photolithography rather than transferring their technology (Kato 2007).

Larger existing firms are observed to have different incentives to innovate than smaller firms including entrepreneurial entrants; see Winter (1984), Acs and Audretsch (1988), and Audretsch (1995b). This suggests opportunities for technology transfers from start-ups to existing firms. Even when existing firms have substantial in-house R&D capabilities, they often rely on independent inventors, partners, and start-ups for technology transfers. Arora, Fosfuri, and Gambardella (2001a) consider the incentives of startups to license their technology. Arora, Fosfuri, and Gambardella (2001a, 2001b) examine the evidence for the existence of international markets for technology and provide extensive analysis of the chemical industry. Blonigen and Taylor (2000) consider acquisition of start-ups by established firms in the US electronics industry. In the international context, Anand and Khanna (2000) find many licensing agreements in chemicals, electronics, and computers. Tilton (1971) and Grindley and Teece (1997) examine licensing in the international diffusion of semiconductors and electronics.

Many innovators choose entrepreneurship over licensing. For example, hundreds of companies entered the early automobile industry. Innovative entrants offered many distinct products as is shown by the significant diversity of models in early automobile manufacturing. A review of the *Standard Catalog of American Cars 1805 to 1942* (Kimes and Clark 1996) shows a vast array of product features and technologies. Additionally, automobile companies differed in terms of manufacturing technologies.[2] Innovation took the form of entrepreneurship in established industries such as retail, wholesale, airlines, computer manufacturing, Internet companies, and media.[3] Hundreds of innovative entrepreneurs entered e-commerce in the dot com boom (Lucking-Reilly and Spulber 2001). Innovators chose entrepreneurship in various types of software (Torrisi 1998), including, for example, encryption software (Giarratana 2004).

2. Bresnahan and Raff (1991) examine intraindustry heterogeneity and the partial diffusion of mass-production technology in the early automobile industry.

3. A number of studies consider entry and exit of innovative producers in the computer industry (McClellan 1984), airlines (Peterson and Glab 1994; Morrison and Winston 1995), and media companies (Maney 1995). Fein (1998) finds shakeouts in wholesaling in over a dozen industries including flowers, woodworking machinery, locksmith, specialty tools and fasteners, sporting goods, wholesale grocers, air conditioning and refrigeration, electronic components, wine and spirits, waste equipment, and periodicals. Management studies have examined competition between innovative start-ups and established firms; see Henderson and Clark (1990) and Christensen (1997).

5.2.2 Multidimensional Innovation and Technology Transfer

Innovation is typically multifaceted. Innovators rarely confine their activities to new products, new production techniques, or new business methods, because they often change many things at once. Jeff Bezos's establishment of Amazon.com involved launching a new brand, introducing new business methods, and applying new e-commerce technologies. Amazon.com provided a product that was differentiated from those of other book retailers. Amazon's business methods as an online retailer differed from traditional "bricks-and-mortar" retailers such as Barnes and Noble or Borders. Amazon.com also introduced new production methods, such as its patented invention of the "1-click" checkout system (method and system for placing a purchase order via a communications network).[4] Amazon.com subsequently licensed its ordering system to Apple for use in its iTunes online store (Kienle et al. 2004).

Schumpeter's (1934, 66) entrepreneur is an innovator who makes "new combinations," which among its elements can simultaneously include the introduction of a new good, the introduction of a new method of production, the opening of a new market, the conquest of a new source of supply of raw materials or half-manufactured goods, and the carrying out of a new organization of any industry. Alfred Chandler (1990, 597) observes that:

> The first movers—those entrepreneurs that established the first modern industrial enterprises in the new industries of the Second Industrial Revolution—had to innovate in all of these activities. They had to be aware of the potential of new technologies and then get the funds and make investments large enough to exploit fully the economies of scale and scope existing in the new technologies. They had to obtain the facilities and personnel essential to distribute and market new or improved products on a national scale and to obtain extensive sources of supply. Finally, they had to recruit and organize the managerial teams essential to maintain and integrate the investment made in the processes of production and distribution.

Kline and Rosenberg (1986, 279) point out that "There is no single, simple dimensionality to innovation. There are, rather, many sorts of dimensions covering a variety of activities."

With multidimensional innovation, technology transfer can involve a bundle of innovations. However, different types of innovations may not be equally transferable. For example, the costs of transferring manufacturing process technologies can differ from the costs of transferring new producing designs. If we lived in a frictionless world, an innovator could perfectly and costlessly transfer any technology to an incumbent firm. Also, in a friction-

4. US Patent 5,960,411; Inventors: P. Hartman, J. P. Bezos, S. Kaphan, and J. Spiegel; Assignee: Amazon.com Inc. Awarded September 28, 1999.

less world, an incumbent could absorb any type of technology and expand its operations to include new products, manufacturing processes, inputs, and transaction methods. In this ideal setting, a profit-maximizing monopolist could always outperform an industry, because profit maximization yields greater profits than competing firms that cannot coordinate their activities. In such a frictionless setting, entrepreneurship will never be observed when there are existing firms. The challenge for researchers is to explain entrepreneurship in an established industry. Clearly, some types of frictions in markets for technology are necessary for entrepreneurship.

There are many standard explanations for frictions in technology transfer. There may be *imperfect intellectual property rights* (IP) so that innovators are reluctant to reveal their technology to the existing firm; see Arrow (1962) and Anton and Yao (1994, 2003). This implies that entrepreneurship is a mechanism for protecting the innovator's intellectual property. There can be *asymmetric information* that results inefficient bargaining between the innovator and the existing firm; see Arrow (1962) and Spulber (2011). Asymmetric information implies that entrepreneurship is a mechanism for internalizing information asymmetries. Technology transfer also can be hindered by the costs of codifying and communicating the inventor's *tacit knowledge;* see Balconi, Pozzali, and Viale (2007) and the references therein. This implies that entrepreneurship is a way for the innovator to apply his tacit knowledge to establish a new firm (Spulber 2010). Technology transfer is also limited by the inability of existing firms to understand or absorb the knowledge; see Acs et al. (2004) on knowledge filters. The transaction costs of technology transfer can be due to the difficulties inherent in negotiating and writing contracts for complex scientific and technological exchanges. These transaction costs are further increased when technology transfer involves contingent contracts that depend on the performance of new technologies and market demand for new products.

In addition to frictions in the market for technology, there can also be frictions in the market for complementary assets. If either the existing firm or the potential entrepreneur has access to complementary assets, they may have an advantage in applying the new technology. These assets may include market knowledge, access to credit, access to customers, and the ability to apply new technologies. Existing firms are already in business, having cleared the regulatory hurdles and made the irreversible investments and incurred the transaction costs necessary to become established. Existing firms offer innovation efficiencies because they have complementary assets such as marketing, sales, and production capabilities; see Teece (1986, 2006).

5.2.3 Technology Transfer and Diversification by Incumbent Firms

Innovations are often bundles of different discoveries. It is likely that technology transfer costs will differ for each component of an innovation. To represent this possibility, I present a model with a two-dimensional innovation involving a new product design and a new production process. The costs of technology transfer imply that one or both components of the innovation may not be transferable to existing firms or to potential entrepreneurs.

In addition to market-related costs of technology transfer, the existing firm faces adjustment costs of adapting to new manufacturing processes and new products. Adjustment costs have traditionally applied to installation of new capital equipment. However, adopting new technologies require firms to adjust their R&D, personnel hiring and training, manufacturing, input procurement, marketing, and sales. Applying new technologies can require fundamental changes in the firm's organizational structure. These adjustment costs conceivably could be greater than the setup costs of establishing a new firm.

If the innovation involves new products, the existing firm can face adjustment costs associated with diversification. A critical determinant of the costs of diversification is the difference between the existing product and the new product. The products may be differentiated horizontally, such as Coke and Diet Coke, or the products may be differentiated vertically, such as Toyota and Lexus. Adjustment costs associated with diversification generate costs of adopting new technologies for incumbent firms that operate existing technologies.

Using illustrations from the history of Microsoft and IBM, Bresnahan, Greenstein, and Henderson (2012) suggest that firms experience diseconomies of scope because their complementary organizational assets need not be suited for multiple markets. The firm's costs of producing multiple products then would be greater than the total costs of single-product firms supplying those products. Therefore, specialized assets and diseconomies of scope imply that diversification by existing firms can be inefficient.

Offering new products, even those that are substitutes for the incumbent's initial product, can require establishing new divisions to handle the different sales channels and marketing required for the new products. This entails costs of establishing the new divisions and costs of coordination across divisions. In some industries, such diversification is feasible and incumbents tend to absorb multiple innovations by adding new products. In other industries, incumbent firms may face limitations on managerial attention that constrain the number of products they produce.

It may simply be a matter of different brands, with little differences in the products' other features. A firm offering multiple brands must adjust its marketing and sales efforts to coordinate its brand portfolio. In some cases, an existing firm diversifies its offerings by extending its brand to a variety of products. An entrepreneurial entrant may create a new brand that is difficult to transfer to an existing firm because its identity is distinct from that of the incumbent. For example, whether the sales channel is online versus bricks-and-mortar affects consumer brand loyalty for retail products (Danaher, Wilson, and Davis 2003). This suggests that a brand identified with the online retailer itself, such as Amazon.com, could be difficult to transfer to a brand identified with a bricks-and-mortar retailer. This is important for our analysis, which considers the possibility that new products are not transferable to an existing firm.

Theoretical models with "persistence of monopoly" or the "efficiency condition" often assume that the incumbent firm can diversify costlessly. Then, an incumbent monopolist can coordinate its prices across multiple differentiated products. This would generate greater profits than a competitive industry for the obvious reason that competition dissipates rents. Such an approach generates a puzzle of entrepreneurship with differentiated products. Rather than establishing a firm, an innovator would always transfer the technology to an incumbent firm who could then diversify and obtain monopoly rents with multiple goods. Again, the only explanation for entrepreneurship would then be frictions in the market for technology transfer. The problem with this approach is that the theoretical analysis implicitly assumes the incumbent can diversify without cost while the entrepreneurial entrant cannot, which is equivalent to assuming the persistence of monopoly. In this setting, the innovator will always prefer transferring the new technology to the incumbent to establishing a new firm.

The cost of developing new products is an important aspect of diversification. Our analysis assumes that the incumbent firm cannot diversify without obtaining a new product design, either through R&D or from an innovator. Klette and Kortum (2004) consider costly diversification in a model with exogenous entry of single-product firms. After entry, existing firms invest in innovation that leads to product diversification. Their discussion focuses on incumbent firm innovation without a market for technology transfer. I examine conditions under which innovators who choose between entrepreneurship and technology transfer have greater incentives to develop new products and new processes than incumbent monopolists. Incumbents diversify only by adopting a new product design, and entrants only offer a single product. A more general framework would allow for multiple products to be offered both by incumbents and by entrants.

5.3 The Strategic Innovation Game

Consider a strategic innovation game played by an innovator and an established firm. The innovator makes a two-dimensional discovery that consists of a new product design and a new production process. The game has two stages. In stage one, the innovator and the incumbent monopolist choose between cooperation and competition. If the innovator and the existing firm choose to cooperate, the innovator can transfer some aspect of the invention to an existing firm, either the new product design, the new production process, or both. Also, as a means of deterring entry, the existing firm can pay the innovator to license the discovery without necessarily adopting the new technology. If the innovator and the incumbent monopolist choose to compete, the innovator can enter the market by becoming an entrepreneur and establishing a new firm to implement the innovation.

Firms implement the innovation, engage in production, and supply products in stage two. If the innovator and the existing firm choose to cooperate in the first stage, the existing firm operates as a monopolist in the second stage. If the innovator and the existing firm do not choose to cooperate in the first stage, then in the second stage, the new firm established by the entrepreneur and the incumbent firm engage in differentiated-products Bertrand-Nash competition, with each firm supplying one good. The new firm established by the entrepreneur employs the new discovery, introducing both the new product design and the new production process.

5.3.1 The Basic Framework

The innovator's discovery consists of a new production process and a new product design. The existing firm's initial production process is represented by unit cost c_1 and the new production process is represented by unit cost c_2. For ease of presentation, assume that the new technology is superior to the existing technology, $c_2 < c_1$. The analysis can be extended readily to allow for the new technology to be inferior, in which case the existing firm would acquire the new production technology to deter entry without applying the new technology.

The existing firm initially is a single-product monopolist. The new product design is horizontally differentiated from the existing product. If the existing firm adopts the new product design, the existing firm becomes a two-product firm. If the innovator becomes an entrepreneur and establishes a firm, the entrant is a single-product firm that produces the new product. Let q_1 be the output of the good initially produced by firm 1. Let q_2 be the new good, which can be supplied by the existing firm through diversification or by the new entrant.

Market demand is derived from the preferences of a representative consumer, $U(q_1, q_2; b)$, where b represents a substitution parameter such that $0 \leq b < 1$. The consumer's utility is quadratic and symmetric in its arguments, so that products are differentiated horizontally,

$$(1) \qquad U(q_1, q_2; b) = 2q_1 + 2q_2 - (1/2)(q_1)^2 - (1/2)(q_2)^2 - bq_1q_2.$$

The representative consumer chooses consumption q_1 and q_2 to maximize surplus, $U(q_1, q_2; b) - p_1q_1 - p_2q_2$. The consumer's demand functions solve the first order conditions, $U_1(q_1, q_2; b) = p_1$ and $U_2(q_1, q_2; b) = p_2$. The consumer's demand functions are

$$q_i = D_i(p_1, p_2; b) = \frac{2 - 2b + bp_j - p_i}{1 - b^2}, \quad i \neq j, i, j = 1, 2.$$

The demand for a good is decreasing in the good's own price and, for $b > 0$, increasing in the price of the substitute good, $\partial D_i(p_1, p_2; b)/\partial p_i < 0$ and $\partial D_i(p_1, p_2; b)/\partial p_j > 0$, $i \neq j$, $i, j = 1, 2$.

To derive the existing firm's monopoly profit, let $q_2 = 0$. The representative consumer's utility function implies that $U(q_1, 0) = 2q_1 - (1/2)(q_1)^2$. The consumer's demand for the incumbent's product is $D_1(p_1) = 2 - p_1$. The monopoly price is $p^m(c_1) = (2 + c_1)/2$ and the existing monopolist's profit equals

$$\Pi^m(c_1) = (p^m(c_1) - c_1)D_1(p^m(c_1)) = (2 - c_1)^2/4. \tag{2}$$

The incumbent monopolist is assumed to be viable with the initial technology, $c_1 < 2$, so that the monopolist also is viable with the new technology.

If the innovator transfers the new product design to the existing firm, the incumbent becomes a two-product monopolist. The profit of a two-product monopolist is given by

$$\Pi^m(c_1, c_2, b) = \max_{p_1,p_2} (p_1 - c_1)D_1(p_1, p_2; b) + (p_2 - c_2)D_2(p_1, p_2; b). \tag{3}$$

With symmetric costs, the profits from producing both goods are greater than the profits from producing only one good for all $b < 1$,

$$\Pi^m(c, c, b) = \frac{2}{1 + b}\frac{(2 - c)^2}{4} > \Pi^m(c).$$

When costs are symmetric, the two-product monopolist's profit is decreasing in the substitution parameter.

5.3.2 Entrepreneurial Entry and Creative Destruction

If the innovator and the existing firm choose to compete, the innovator becomes an entrepreneur by establishing a new firm that embodies the new product design and the new production technology. The existing firm continues to produce a single product with the existing technology. Designate the existing firm as firm 1 and the market entrant as firm 2. The incumbent firm and the entrepreneurial entrant engage in Bertrand-Nash price competition with differentiated products. The Bertrand-Nash equilibrium prices $p_1{}^*$ and $p_2{}^*$ solve

$$\Pi_1(c_1, c_2, b) = \max_{p_1} (p_1 - c_1)D_1(p_1, p_2{}^*; b) \tag{4}$$

$$\Pi_2(c_1, c_2, b) = \max_{p_2} (p_2 - c_2)D_2(p_1{}^*, p_2; b). \tag{5}$$

The equilibrium prices depend on the costs of the two firms and the product differentiation parameter, $p_1{}^*(c_1, c_2, b)$ and $p_2{}^*(c_1, c_2, b)$. We restrict attention to cost values such that outputs and profits are nonnegative for both firms. For $b = 0$, each of the firms is a monopolist.

The intensity of product-market competition depends positively on the substitution parameter b and on the difference between costs. With duopoly competition, the price functions are

(6) $p_i^*(c_1, c_2, b) = [2c_i + bc_j + 2(2 + b)(1 - b)]/(4 - b^2), \quad i \neq j, i, j = 1, 2.$

When duopoly output levels are positive they equal

$$(7) \qquad q_i^*(c_1, c_2) = \frac{(2 - b^2)(2 - c_i) - b(2 - c_j)}{(1 - b^2)(4 - b^2)}, \quad i \neq j, i, j = 1, 2.$$

The profits of the firms are

$$(8) \qquad \Pi_i(c_i, c_j, b) = \frac{[(2 - b^2)(2 - c_i) - b(2 - c_j)]^2}{(1 - b^2)(4 - b^2)^2}, \quad i \neq j, i, j = 1, 2.$$

Both firms operate profitably in equilibrium when the new technology is close to the existing technology because positive profits follows from $2 > b^2 + b$. Profits are decreasing in the firm's own cost, $\partial\Pi_i(c_i, c_j, b)/\partial c_i < 0$ and increasing in the competitor's cost, $\partial\Pi_i(c_i, c_j, b)/\partial c_j > 0$, $i \neq j$, $i = 1, 2$. For $b > 0$, the firms' costs are substitutes in the profit functions, $\partial^2\Pi_i(c_i, c_j, b)/\partial c_i\partial c_j < 0$, $i \neq j$, $i = 1, 2$.

Because the new technology is superior to the existing technology, both firms operate when the incumbent firm operates profitably. If the entrepreneurial entrant is sufficiently efficient, it drives out the incumbent firm. From equation (7), $q_1 = 0$ defines the cost threshold $c_2^0(b, c_1)$ for firm 2,

$$(9) \qquad c_2^0(b, c_1) = \frac{2b - (2 - b^2)(2 - c_1)}{b}.$$

Zanchettin (2006) shows that only the entrant operates when costs are less than or equal to the threshold, $c_2 \leq c_2^0(b, c_1)$, and both firms operate when the entrant's costs are above the threshold, $c_2 > c_2^0(b, c_1)$. The cost threshold for the new technology is less than the initial technology, $c_2^0(b, c_1) < c_1$, and is increasing in the substitution parameter, b. If the innovation is sufficiently drastic, then the entrepreneurial entrant can drive out the incumbent by offering a monopoly price, $p^m(c_2) = (2 + c_2)/2$. Driving out the incumbent with monopoly pricing occurs when the invention is sufficiently drastic. This occurs when the entrant's costs are below a lower threshold, $c_2 \leq c_2^{00}(b, c_1)$, which exists only if $c_1 + b < 2$,

$$(10) \qquad c_2^{00}(b, c_1) = \frac{2(c_1 + b - 2)}{b} < c_2(b, c_1).$$

When the innovation is below the threshold $c_2^0(b, c_1)$ but not sufficiently drastic, $2(c_1 + b - 2)/b < c_2 \leq c_2^0(b, c_1)$, the more efficient firm engages in limit pricing to deter the higher-cost firm from operating. The entrepreneurial entrant, firm 2, is the limit-pricing firm, and firm 1's output is $q_1 =$

$2(1 - b) - p_1 + bp_2 \leq 0$. Then, firm 2's reaction function becomes $p_2 = (1/b)[p_1 - 2(1 - b)]$. The incumbent firm 1 has a zero output and chooses $p_1 = c_1$. The limit-pricing entrant, firm 2, produces output greater than the monopoly output $q_2^L(c_1, c_2) = 2 - p_2 = (2 - c_2)/b > q^m(c_2) = (2 - c_2)/2$, and sets a price below the monopoly price, $p_2^L(c_1, c_2, b) = (1/b)[c_1 - 2(1 - b)] < p^m(c_2) = 1 + c_2/2$. The limit-pricing firm earns profits less than monopoly profits,

$$\Pi_2^L(c_1, c_2, b) = \frac{(2 - c_1)[b(2 - c_2) - (2 - c_1)]}{b^2} < \Pi^m(c_2) = \frac{(2 - c_2)^2}{4}.$$

The properties of the profit and price functions hold more generally. For additional discussion of the class of utility functions that yield similar properties for comparative statics analysis of a duopoly equilibrium, see Milgrom and Roberts (1990). For differentiated duopoly with symmetric costs, see Singh and Vives (1984), and for differentiated duopoly with asymmetric costs and qualities, see Zanchettin (2006). The analysis can be extended to other differentiated product settings such as Hotelling-type (1929) price competition. The results of the following analysis do not require price competition. They could be examined with the two firms engaging in Cournot quantity competition with differentiated products.

5.3.3 Cooperation versus Competition

If the innovator and the incumbent firm choose to cooperate, the incumbent firm is a monopolist with profits Π^m that will depend on what technology is transferred. If the innovator and the incumbent firm choose to compete, the incumbent firm earns duopoly profits, $\Pi_1(c_1, c_2, b)$ and the entrepreneurial entrant earns duopoly profits, $\Pi_2(c_1, c_2, b)$. The incumbent firm's net benefit from adopting the new technology offered by the innovator equals the difference between monopoly profits at the new technology and duopoly profits when the incumbent has the old technology and the entrant has the new technology. Therefore, the incumbent firm's net benefit from adopting the new technology equals the incremental returns from remaining a monopolist, $\Pi^m - \Pi_1$. This is the maximum amount that the innovator can obtain from transferring the technology to the incumbent firm.

The outcome of the strategic innovation game depends on the total returns to cooperation and competition for the innovator and the incumbent firm. The innovator and the incumbent prefer entrepreneurship to technology transfer if and only if the returns to entry are greater than the incremental returns to the incumbent firm from technology transfer,

$$\Pi_2 > \Pi^m - \Pi_1.$$

This is equivalent to the condition that total industry profits when the incumbent firm has the initial technology and the entrepreneurial firm has the new technology are greater than monopoly profits at the new technology,

$$\Pi_1 + \Pi_2 > \Pi^m.$$

If this condition holds, the innovator with a superior technology will become an entrepreneur and enter the market. If this condition does not hold, full information bargaining will result in the innovator transferring his technology to the incumbent.

For the innovator and the incumbent firm to choose competition over cooperation, the incumbent firm using the new technology must earn lower profits than the competitive industry. The possibility of entrepreneurial entry may seem counterintuitive because it may appear that the monopolist will always earn greater profits than the competitive industry. The outcome of the strategic innovation game between the innovator and the existing firm depends on the extent of the innovation. The greater the difference between costs with the new technology and costs with the initial technology, the higher the quality of the process innovation. The value of the product innovation depends on the incremental returns to diversification by the incumbent firm.

If the innovator and the established firm choose cooperation, they bargain over the royalty, R. Let the relative bargaining power of the innovator in the bargaining game be represented by the parameter, α, where $0 \leq \alpha \leq 1$. This represents the reduced form of a bargaining game between the innovator and the incumbent firm. This can represent bargaining with alternating offers and discounting of future payoffs or first-and-final offers by either party. Because there is a lump-sum royalty, bargaining is efficient and relative bargaining power does not affect the outcome of the strategic innovation game. With full information, the outcome of the strategic innovation game is efficient for the innovator and the incumbent firm. They decide whether to cooperate or to compete and if cooperation is efficient they bargain over the division of the surplus. The innovator receives a royalty from transferring the technology equal to $R = \alpha(\Pi^m - \Pi_1) + (1 - \alpha)\Pi_2$.

5.4 Equilibrium of the Strategic Innovation Game

Due to various transaction costs, the invention may be imperfectly transferable. The transferability of the invention will affect the outcome of the strategic interaction between the existing firm and the innovator. Transferability will affect the returns to licensing the invention and it will affect whether the existing firm and the innovator choose to compete or to cooperate. Because the innovation is two dimensional there are four possibilities: (1) the new technology is fully transferable, that is both the new product design and the new production process are transferable and the new production process is applicable to producing both goods; (2) the new technology is nontransferable; that is, neither the new product design nor the production technology are transferable, although the existing firm can still license the new technology as a means of deterring entry, without using the new technology; (3) the new product design is not transferable and the new production process is transferable, so the existing firm can apply the production process to the initial good; and (4) finally, if the new product design is transferable but the new production process is not transferable, then the existing firm produces both the initial product and the new product, and applies the initial production process to both products.

5.4.1 Fully Transferable Technology

With fully transferable technology, the existing firm obtains profit from producing both goods using the new production technology, $\Pi^m(c_2, c_2, b)$. If the innovator and the incumbent firm choose to compete, the incumbent firm earns duopoly profits, $\Pi_1(c_1, c_2, b)$ and the entrepreneurial entrant earns duopoly profits, $\Pi_2(c_1, c_2, b)$. Total industry profits are continuous in the new process technology c_2 and the curve representing total profits has up to three segments. If the innovation is sufficiently drastic, $c_2 \leq c_2^{00}(c_1, b)$, then a monopoly-pricing entrant eliminates the incumbent and industry profits equal single-product monopoly profits with the new process technology.

$$\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) = \Pi^m(c_2).$$

For an intermediate value of the new process technology, $c_2^{00}(c_1, b) < c_2 \leq c_2^0(c_1, b)$, the entrepreneurial entrant engages in limit pricing so that industry profits equals

$$\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) = \Pi_2^L(c_1, c_2, b) < \Pi^m(c_2).$$

These two situations correspond to creative destruction. Finally, for incremental innovations, $c_2^0(c_1, b) < c_2 < c_1$, both firms operate and total industry profits are calculated by adding the two firms' profits using equation (8). With both firms operating, industry profits are decreasing and convex in c_2. As c_2 approaches c_1, total industry profits approaches its minimum for $c_2 \leq c_1$,

$$\Pi_1(c_1, c_1, b) + \Pi_2(c_1, c_1, b) = (2 - c_1)^2 \frac{2(1 - b)}{(1 + b)(2 - b)^2} \tag{11}$$

This is the minimum for the three segments, as shown in figure 5.1.

With fully transferable technology, the returns to cooperation exceed the returns to competition. The monopolist with the new product design and the new production process earns more than industry profits with entrepreneurial entry for all $b > 0$,

$$\Pi^m(c_2, c_2, b) > \Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b).$$

This holds because of the rent-dissipating effects of competition and because the incumbent uses the old production process when there is entrepreneurial entry. The net returns to technology transfer, $\Pi^m(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$, are

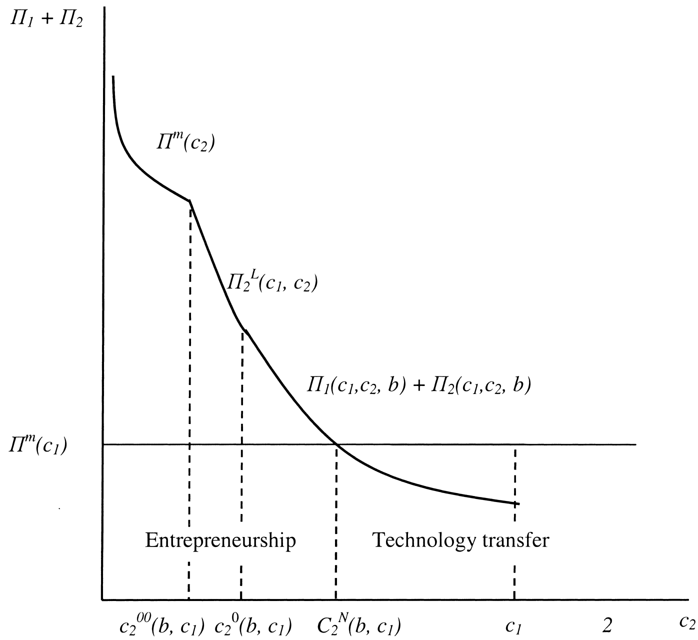

Fig. 5.1 With nontransferable technology, the outcome of the innovation game is entrepreneurship only if the new process innovation, c_2, is sufficiently below the initial cost, that is, if the new costs are less than a critical value, $C_2^N(b, c_1)$, where $C_2^N(b, c_1) \leq c_1$

greater than the returns to entrepreneurship, $\Pi_2(c_1, c_2, b)$. This immediately implies that when technology is fully transferable, the innovator and the existing firm always choose to cooperate.

Proposition 1. *With fully transferable technology, entrepreneurial entry does not occur and the innovator transfers the technology to the existing firm.*

Proposition 1 yields insights into Kenneth Arrow's (1962) original investigation of the incentive to invent. The incumbent monopolist's incentive to invent equals the returns to producing both goods and applying the new process technology,

$$V^m = \Pi^m(c_2, c_2, b) - \Pi^m(c_1). \tag{12}$$

Although generalized to include diversification, the monopolist's incentive to invent reflects the inertia identified by Arrow. The firm that expects to continue to be a monopolist is concerned only about incremental profits.

Now, compare the monopolist's incentive to invent with that of the innovator. With fully transferable technology, the innovator's incentive to invent equals the royalties from technology transfer,

$$V^I = R = \alpha(\Pi^m(c_2, c_2, b) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b). \tag{13}$$

The innovator's incentive to invent derives from transferring the technology or from competing with the incumbent firm. If the innovator licenses the technology to the incumbent monopolist, the incumbent monopolist's willingness to pay is the difference between the incumbent's monopoly profit and the incumbent's profit after competitive entry. Due to the effects of competition, the incumbent's initial profit is greater than the incumbent's profit after entry, $\Pi^m(c_1) > \Pi_1(c_1, c_2, b)$. So, the monopolist's incentive to invent is less than the benefit of adopting the new technology,

$$V^m = \Pi^m(c_2, c_2, b) - \Pi^m(c_1) < \Pi^m(c_2, c_2, b) - \Pi_1(c_1, c_2, b).$$

The innovator's incentive to invent is greater than or equal to the returns to entrepreneurial entry and less than or equal to the incumbent's benefit from technology adoption. Define the critical value of the innovator's bargaining power by

$$\alpha^* = \frac{\Pi^m(c_2, c_2, b) - \Pi^m(c_1) - \Pi_2(c_1, c_2, b)}{\Pi^m(c_2, c_2, b) - \Pi_1(c_1, c_2, b) - \Pi_2(c_1, c_2, b)}. \tag{14}$$

PROPOSITION 2. *With fully transferable technology, the innovator's incentive to invent is greater than that of the incumbent monopolist if and only if the innovator has sufficient bargaining power,* $\alpha \geq \alpha^*$.

With fully transferable technology and sufficient bargaining power, the possibility of entrepreneurship increases incentives to invent. Even though the innovator transfers the technology to the incumbent firm, the possibility of entrepreneurship overcomes the incumbent firm's inertia. The threat of creative destruction provides a competitive benchmark that increases the incumbent's incentive to adopt in comparison to the monopoly benchmark.

5.4.2 Nontransferable Technology

Suppose that neither the new product design nor the new production process is transferable. The innovator can still contract with the existing firm to receive a payment for not entering the market, with the incumbent licensing the technology without actually using the new product design or the new production process.[5] The existing firm that buys out the innovator would continue to operate as a single-product monopoly with profits, $\Pi^m(c_1)$. The lowest value of industry profits, $\Pi_1(c_1, c_1, b) + \Pi_2(c_1, c_1, b)$, is greater than, equal to, or less than the incumbent's profits, $\Pi^m(c_1)$ depending on the substi-

5. Rasmusen (1988) considers an entrant that seeks a buyout after entry in a homogeneous-products Cournot game with capacity constraints, although he does not consider technological change.

tution parameter. Entrepreneurial entry need not always occur because the innovator and the existing firm still have incentives to avoid competition.

For a given degree of product differentiation, entrepreneurial entry occurs if the process innovation is sufficiently large. With nontransferable technology, the incumbent and the entrant have greater incentives to cooperate to avoid creative destruction only when the innovation is incremental, as shown in figure 5.1. With nontransferable technology, a significant innovation increases the returns to entry for the entrepreneur who drives out the incumbent. The pure creative destruction effect means that the entrepreneur's returns to entry exceed the benefits to the incumbent from buying out the innovator.

With nontransferable technology, entry occurs if and only if the substitution parameter is either above or below an intermediate range, as shown in figure 5.2. With vigorous competition resulting from less product differentiation, the innovator and the existing firm have less incentive to cooperate because the entrepreneurial entrant will displace the incumbent firm. With less competition resulting from more product differentiation, the innovator and the existing firm also have less incentive to cooperate because they earn sufficient profits after entrepreneurial entry.

Proposition 3. *With nontransferable technology, entrepreneurial entry occurs if and only if the substitution parameter is less than the critical value* $b^N = b^N(c_1, c_2)$ *or greater than the critical value* $b^{NN} = b^{NN}(c_1, c_2)$, *where* $b^N(c_1, c_2) < b^{NN}(c_1, c_2)$. *Also, with nontransferable technology, entrepreneurial entry occurs if and only if costs are less than the critical value,* $C_2^N(b, c_1)$, *where* $C_2^N(b, c_1) \leq c_1$, *so that significant process innovations result in entrepreneurship.*

Proof. First, we show that the industry profits function is continuous in b with three segments. Using the quadratic formula, the critical value $0 < b^0 < 1$ that solves $c_2 = c_2^0(b^0, c_1)$ is given by

$$b^0 = \frac{-(2 - c_2) + [(2 - c_2)^2 + 8(2 - c_1)^2]^{1/2}}{2(2 - c_1)}.$$

The critical value b^{00} that solves $c_2 = c_2^{00}(b^0, c_1) = 2(c_1 + b^{00} - 2)/b^{00}$ is given by

$$b^{00} = \frac{2(2 - c_1)}{2 - c_2}.$$

For $0 \leq b < b^0$, both firms operate profitably so that industry profits equal

$$\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) = \frac{(4 - 5b^2 + b^4)A - (4b - 2b^3)B}{(1 - b^2)(4 - b^2)^2}, \tag{15}$$

where $A = (2 - c_1)^2 + (2 - c_2)^2$ and $B = 2(2 - c_1)(2 - c_2)$. For $b^0 \leq b < b^{00}$, limit pricing occurs so that only firm 2 operates profitably and industry profits are equal to

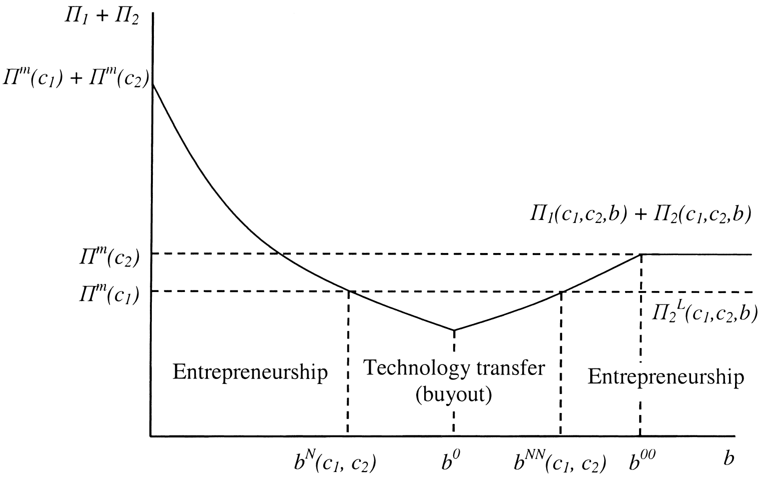

Fig. 5.2 With nontransferable technology, the outcome of the innovation game is entrepreneurship if and only if the substitution parameter is less than the critical value $b^N = b^N(c_1, c_2)$ or greater than the critical value $b^{NN} = b^{NN}(c_1, c_2)$

$$(16)\qquad \Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) = \Pi_2^L(c_1, c_2, b) = \frac{(2 - c_1)[b(2 - c_2) - (2 - c_1)]}{b^2}.$$

There is a third region only if the invention is sufficiently drastic, $2(2-c_1) < (2-c_2)$. Then, for $b^{00} \leq b < 1$, the entrant deters the incumbent with monopoly pricing and industry profits equal the entrant's profits, $\Pi^m(c_2)$. The industry profits function is continuous at b^0, because $c_2 = c_2(b^0, c_1)$ so that from equation (16),

$$(17)\quad \Pi_1(c_1, c_2, b^0) + \Pi_2(c_1, c_2, b^0) = \frac{(2 - c_2)^2[1 - (b^0)^2]}{[2 - (b^0)^2]^2} = \Pi_2^L(c_1, c_2, b^0).$$

The industry profits function is continuous at b^{00}, because $c_2 = 2(c_1 + b^{00} - 2)/b^{00}$ so that industry profits equal

$$(18)\qquad \Pi_2^L(c_1, c_2, b^{00}) = \frac{(2 - c_2)^2}{4} = \Pi^m(c_2).$$

For $0 \leq b < b^0$, the industry profits function in equation (15) is strictly decreasing in b. Differentiating with respect to b gives

$$\frac{\partial(\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b))}{\partial b} = \frac{2[b(4 - 9b^2 + 2b^4 - b^6)A - (8 + 2b^2 - 5b^4 + 3b^6)B]}{(1 - b^2)^2(4 - b^2)^3}.$$

Note that $(8 + 2b^2 - 5b^4 + 3b^6) > 0$ for $0 \le b < 1$. If $(4 - 9b^2 + 2b^4 - b^6) \le 0$ it follows that $\partial(\Pi_1(c_1, c_2; b) + \Pi_2(c_1, c_2; b))/\partial b < 0$. Conversely, suppose that $(4 - 9b^2 + 2b^4 - b^6) > 0$. Note that when c_2 is above the threshold, it follows that $(2 - b^2)B > bA$, so that again $\partial(\Pi_1(c_1, c_2; b) + \Pi_2(c_1, c_2; b))/\partial b < 0$. For $b^0 \le b \le b^{00}$, $\Pi_2^L(c_1, c_2, b)$ is strictly increasing in b because $b < b^{00}$. The analysis shows that there exists a unique critical value of the substitution parameter, $b^N(c_1, c_2) < b^0 < 1$ that solves

$$\Pi_1(c_1, c_2, b^N) + \Pi_2(c_1, c_2, b^N) = \Pi^m(c_1). \tag{19}$$

Also, there is a critical value $b^0 < b^{NN}(c_1, c_2) < 1$ that equates industry profits with the incumbent's profits at the initial technology. So, industry profits are greater than the monopolist's profits at the new technology if and only if either $0 \le b < b^N(c_1, c_2)$ or $b^{NN}(c_1, c_2) \le b < 1$. Because the industry profits curve is downward sloping in the new process technology, and minimum industry profits are greater than, equal to or less than $\Pi^m(c_1)$ depending on the substitution parameter, it follows that entrepreneurial entry occurs if and only if costs c_2 are less than the critical value $C_2^N(b, c_1) \le c_1$. ■

With nontransferable technology, entrepreneurship takes place only if the innovation is significant. The critical cost value, $C_2^N(b, c_1)$ is less than c_1 only if industry profits in equation (11) are less than $\Pi^m(c_1)$. When the substitution parameter b is sufficiently low, competition is mitigated so that entrepreneurial entry takes place for any cost level, so that the critical value $C_2^N(b, c_1)$ equals c_1.

The incumbent monopolist can have greater incentives to invent than the innovator because nontransferable technology reduces the returns from licensing.

PROPOSITION 4. *With nontransferable technology, the incumbent monopolist has a greater incentive to invent than the innovator when products are sufficiently differentiated,*

$$b \le \frac{\Pi^m(c_2) - \Pi^m(c_1)}{\Pi^m(c_2) + \Pi^m(c_1)}.$$

PROOF. Recall that the profits of the two-product monopolist with the initial technology equals $\Pi^m(c, c; b) = 2[2/(1 + b)][(2 - c)^2/4]$. If the outcome of the innovation game is entrepreneurship, the innovator obtains $V^I = \Pi_2(c_1, c_2; b)$. Then,

$$\begin{aligned} V^m - V^I &= \Pi^m(c_2, c_2, b) - \Pi^m(c_1) - \Pi_2(c_1, c_2; b) \\ &= \{\Pi^m(c_2) - \Pi_2(c_1, c_2; b)\} + \left[\frac{1 - b}{1 + b}\Pi^m(c_2) - \Pi^m(c_1)\right] > 0. \end{aligned}$$

The first term is positive due to the effects of competition and the second term is positive from the upper limit on b. If the outcome of the innovation game is licensing, the innovator obtains $V^I = R = \alpha(\Pi^m(c_1) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b)$, so that $V^I \leq \Pi^m(c_1) - \Pi_1(c_1, c_2, b)$. Then,

$$V^m - V^I \geq \Pi_1(c_1, c_2, b) + 2\{[1/(1 + b)]\Pi^m(c_2) - \Pi^m(c_1)\}.$$

The second term is positive for $b \leq [\Pi^m(c_2) - \Pi^m(c_1)]/[\Pi^m(c_1)]$, which holds from the upper limit on b, so that again $V^m > V^I$. ■

Nontransferable technology reduces incentives to invent because the innovator obtains returns from entrepreneurial entry or from a buyout to prevent entry. Greater product differentiation is sufficient for the monopolist's incentive to invent to exceed the returns from entry or from a buyout.

5.4.3 Only the New Production Process is Transferable

If the new product design is not transferable and the new production process is transferable, then with technology transfer the existing firm remains a single-product monopolist and obtains profit using the new production technology, $\Pi^m(c_2)$. Therefore, the incumbent firm's net benefit from adopting the new technology equals the incremental returns from remaining a monopolist, $\Pi^m(c_2) - \Pi_1(c_1, c_2, b)$. This is the maximum amount that the innovator can obtain from transferring the technology to the incumbent firm.

The outcome of the strategic innovation game depends on the total returns to cooperation and competition for the innovator and the incumbent firm. The innovator prefers entrepreneurship to technology transfer if and only if the returns to entry are greater than the incremental returns to the incumbent firm from technology transfer, $\Pi_2(c_1, c_2, b) > \Pi^m(c_2) - \Pi_1(c_1, c_2, b)$. This is equivalent to the condition that total industry profits when the incumbent firm has the initial technology and the entrepreneurial firm has the new technology are greater than monopoly profits at the new technology,

$$\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) > \Pi^m(c_2).$$

Product differentiation makes entrepreneurial entry possible even when the innovator can transfer only the new production process. When products are not close substitutes, the total profits of the incumbent firm and the entrant are greater than the profits of the existing firm with the new production technology. Without competition ($b = 0$), industry profits exceed the incumbent's profits evaluated at the new technology,

$$\Pi_1(c_1, c_2, b = 0) + \Pi_2(c_1, c_2, b = 0) = \Pi^m(c_1) + \Pi^m(c_2) > \Pi^m(c_2).$$

For b near zero, the threshold $c_2^0(b, c_1)$ is less than or equal to 0, so that limit pricing is ruled out for b near zero and both firms operate profitably. The threshold $c_2^0(b, c_1)$ is increasing in b and approaches c_1 as b goes to 1. When products are not close substitutes, both firms operate and the industry earns greater profits than a single-product monopolist using the new production process. As the degree of product substitution increases, industry profits decrease and eventually the lower-cost firm is able to displace the incumbent firm through limit pricing. This reduces industry profits to the profits of the entrepreneurial entrant that are less than the profits of a single-product monopolist using the new production process. With limit pricing, the lower-cost firm's profits are increasing in the degree of product substitution. When products are very close substitutes, and the invention is sufficiently drastic, the more efficient entrant with monopoly pricing can displace the incumbent using the initial technology. Then, transferring the technology generates the same profits as entrepreneurial entry.

Because the industry profits curve is downward sloping in the new process technology, there exists a unique cost threshold C_2^*, where $c_2^0(c_1, b) < C_2^*(c_1, b) \leq c_1$, such that

$$\Pi_1(c_1, C_2^*, b) + \Pi_2(c_1, C_2^*, b) = \Pi^m(C_2^*). \tag{20}$$

The cost threshold is illustrated in figure 5.3. When the process innovation is significant, industry profits with competition are less than or equal to the profits of a single-product monopoly, thus leading to cooperation and technology transfer. The result establishes a critical threshold for technology transfer that is greater than the critical threshold for limit pricing. Below

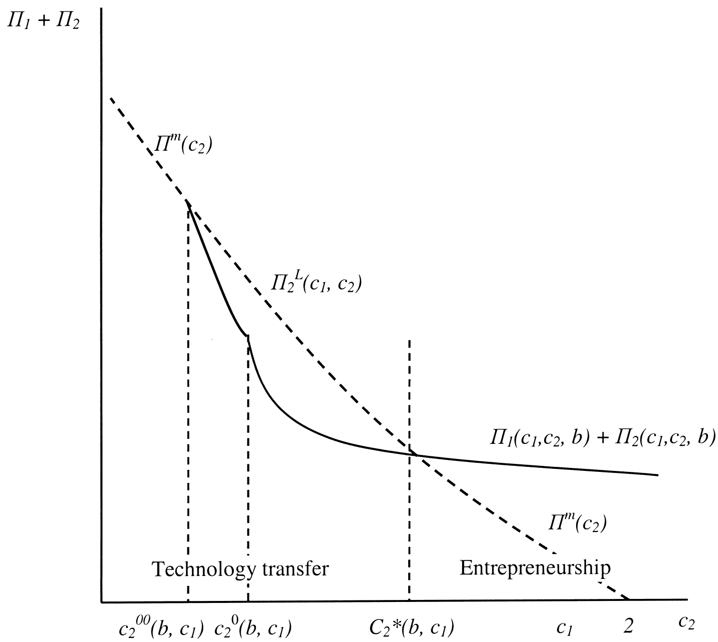

Fig. 5.3 When only the production process is transferable, the outcome of the innovation game is entrepreneurship if and only if the new process technology is incremental, $c_2 > C_2^*(c_1, b)$

that threshold, technology transfer is preferable to entrepreneurship for the innovator and the existing firm. If $c_2 \leq c_2(c_1, b)$, the returns to technology transfer outweigh the profit of the entrepreneurial entrant that drives out the incumbent, either through limit pricing, or when the invention is drastic, with a monopoly price. This implies that there is an additional range of costs, $c_2(c_1, b) < c_2 \leq C_2^*(c_1, b)$, such that the returns to technology transfer outweigh industry profits even when both firms operate after entry.

Sufficiently differentiated products or incremental innovations generate entrepreneurship when only the production process is transferable.

Proposition 5. *When only the production process is transferable, entrepreneurial entry occurs when products are differentiated sufficiently, $0 \leq b < b^*(c_1, c_2)$, where the threshold $b^*(c_1, c_2)$ is unique, positive and less than one. Also, there exists a positive critical value of the new technology, $C_2^*(c_1, b)$, such that entrepreneurship occurs in equilibrium when the process innovation is incremental, $c_2 > C_2^*(c_1, b)$. The cost threshold is greater than that for limit pricing and less than or equal to the initial technology, $c_2^0(c_1, b) < C_2^*(c_1, b) \leq c_1$.*

Proposition 5 illustrates Schumpeter's observation that the entrepreneur will enter beside the existing firm. Sufficient product differentiation attenuates competition so that industry profits are greater than monopoly profits using the new production technology and the innovator obtains greater returns from entrepreneurship than from technology transfer. Because product differentiation limits product market competition, entrepreneurship also can occur when the new production technology is inferior to the incumbent's production technology.

Additionally, entrepreneurship is associated with incremental process inventions while technology transfer is associated with significant process inventions. With significant improvements in production technology, cost savings and monopoly profits outweigh the returns to product differentiation and entry so that the incumbent firm and the innovator choose cooperation over competition. With incremental improvements in technology, innovators embody their discoveries in new firms offering new products and creative destruction occurs at the margin. When entrepreneurial entry occurs in waves as Schumpeter suggested, each new entrant will introduce new products and incremental process innovations.

The industry profits function is decreasing in the substitution parameter when both firms operate profitably so that the cost threshold in Proposition 5 is increasing in the substitution parameter, $\partial C_2^*(b, c_1)/\partial b \geq 0$. This implies that with greater product differentiation, that is, with lower values of b, the cost threshold falls and the range of innovations that result in entrepreneurship increases.

Corollary 1. *With a transferable production process, greater product differentiation (lower b) implies an increase in the range of innovations for* *which entrepreneurship occurs, with the marginal process innovation at which entrepreneurship occurs becoming more significant.*

The effects of product differentiation suggest potential industry dynamics. Suppose that the substitution parameter initially takes a high value. Then, a series of innovators with superior process technologies will choose to sell their idea to the incumbent firm, which experiences technological improvements. Then, suppose that the substitution parameter declines over time. For a particular process innovation, the outcome of the innovation game would switch from technology transfer to entrepreneurial entry. In contrast, with a rising substitution parameter, the outcome of the innovation game would switch from entrepreneurial entry to technology transfer.

When only the production process is transferable, the innovator's incentive to invent both a new product and a new process technology reflects the returns from commercializing the process invention through licensing or through entrepreneurship. The innovator's incentive to invent equals

$$(21) \quad V^I = \max \{\alpha(\Pi^m(c_2) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b), \Pi_2(c_1, c_2, b)\}.$$

For purposes of comparison, consider the incumbent monopolist's incentive to invent only a new process technology, $V^m = \Pi^m(c_2) - \Pi^m(c_1)$. The incumbent firm using its initial technology earns more as a monopolist than with competitive entry, $\Pi^m(c_1) > \Pi_1(c_1, c_2, b)$. This implies that the monopolist's incentive to invent is less than the benefit of adopting the new technology,

$$V^m = \Pi^m(c_2) - \Pi^m(c_1) < \Pi^m(c_2) - \Pi_1(c_1, c_2, b).$$

If entrepreneurial entry is more profitable than the monopolist's returns to technology transfer, that is $\Pi^m(c_2) - \Pi_1(c_1, c_2, b) \leq \Pi_2(c_1, c_2, b)$, the entrepreneur's incentive to invent a new product and process is greater than the monopolist's incentive to invent a new production process.

PROPOSITION 6. *Consider incentives to invent when only the new production process is transferable. When products are sufficiently differentiated,* $0 \leq b \leq b^*(c_1, c_2)$, *or when the process innovation is incremental,* $c_2 > C_2^*(c_1, b)$, *the innovator's incentive to invent is greater than that of an incumbent monopolist,* $V^I > V^m$.

This result holds for all values of the bargaining power parameter. When technology transfer is the equilibrium outcome, the innovator's incentive to invent may be lower than that of the monopolist when bargaining power is low.

For any given level of product differentiation, the innovator's incentive to invent depends on the relative bargaining power of the innovator and incumbent firm. We can then define a critical value of the product differentiation parameter, $\alpha^* = \max \{0, \alpha'\}$, where

$$(22) \qquad \alpha' = \frac{\Pi^m(c_2) - \Pi^m(c_1) - \Pi_2(c_1, c_2, b)}{\Pi^m(c_2) - \Pi_1(c_1, c_2, b) - \Pi_2(c_1, c_2, b)}.$$

When the innovator has sufficient bargaining power, that is, $\alpha^* \leq \alpha \leq 1$, the innovator's incentive to invent, V^I, is greater than that of an incumbent monopolist, V^m, whether or not the new technology improves on the existing technology.[6]

The innovative monopolist experiences inertia because of initial monopoly profit. When an innovator provides an invention to the incumbent firm, the threat of entry provides a benchmark that is less than monopoly profits, which reduces the monopolist's inertia. The incumbent monopolist compares the profits from technology adoption to profit after entry of the entrepreneur. The innovator's incentive to invent reflects the returns to technology transfer and entrepreneurial entry. If the innovator becomes an entrepreneur, the return from entry must be greater than what could be obtained from transferring the technology to the incumbent. The innovator's return from being an entrepreneur is obtained by competing with the incumbent firm. Therefore, the innovator's total rents derive from the returns to differentiated products competition.

5.4.4 Only the New Product Design is Transferable

If the new product design is transferable but the new production process is not transferable, then with technology transfer the existing firm obtains profit from producing both goods using the initial technology, $\Pi^m(c_1, c_1, b)$. The innovator prefers entrepreneurship to technology transfer if and only if the returns to entry are greater than the incremental returns to the incumbent firm from technology transfer,

$$\Pi_2(c_1, c_2, b) > \Pi^m(c_1, c_1, b) - \Pi_1(c_1, c_2, b).$$

This is equivalent to the condition that total industry profits when the incumbent firm has the initial technology and the entrepreneurial firm has the new technology are greater than monopoly profits with the new product design and the initial production process,

$$\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b) > \Pi^m(c_1, c_1, b).$$

6. The innovator's incentive to invent when the new technology is equivalent or inferior to that of the incumbent firm, $c_2 \geq c_1$, equals

$$V^I = \max\{\alpha(\Pi^m(c_1) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b), \Pi_2(c_1, c_2, b)\}.$$

The innovator's incentive to invent is positive even with an equivalent or inferior technology. The incumbent monopolist would have an incentive to invent equal to zero if the new technology were equivalent or inferior to the existing technology, $V^m = 0$. Then, $V^I > 0 = V^m$, so the innovator's incentive to invent is always greater than that of an incumbent monopolist. This holds for all values of the substitution parameter.

When the substitution parameter equals zero, industry profits exceed the incumbent's profits evaluated at the initial production technology due to a pure efficiency effect,

$$\begin{aligned}\Pi_1(c_1, c_2, b = 0) + \Pi_2(c_1, c_2, b = 0) &= \Pi^m(c_1) + \Pi^m(c_2)\\ &> 2\Pi^m(c_1)\\ &= \Pi^m(c_1, c_2, b = 0).\end{aligned}$$

However, when products are closer substitutes, competition between the entrant and the incumbent firm diminishes the benefits of entrepreneurial entry in comparison with technology transfer. Industry profits are decreasing in the substitution parameter, although the monopolist's profits also are decreasing in the substitution parameter.

The lowest value of industry profits is less than the profit of the incumbent monopolist that produces two products with the initial process technology, for all positive b,

$$\Pi_1(c_1, c_1, b) + \Pi_2(c_1, c_1, b) = \frac{4 - 4b}{4 - 4b + b^2}\,\Pi^m(c_1, c_1, b) < \Pi^m(c_1, c_1, b).$$

This implies that entrepreneurship occurs if and only if the substitution parameter is outside an intermediate range.

The transferability of the new product design reverses the previous result with a transferable process technology. There is a critical cost threshold that solves

$$\Pi_1(c_1, c_2^D, b) + \Pi_2(c_1, c_2^D, b) = \Pi^m(c_1, c_1, b).$$

The lowest value of industry profits is greater than the profits of the two-product monopolist at $b = 0$. Then, the cost threshold c_2^D goes to c_1, so that all innovators choose to become entrepreneurs. For sufficiently differentiated products, the lowest value of industry profits is greater than the profits of the two-product monopolist so that the cost threshold c_2^D is strictly less than c_1. Incremental process innovations result in technology transfer and significant innovations generate entrepreneurship.

PROPOSITION 7. *When only the new product design is transferable, entrepreneurial entry occurs if and only if the substitution parameter is less than the critical value* $b^D = b^D(c_1, c_2)$ *or greater than the critical value* $b^{DD} = b^{DD}(c_1, c_2)$*. Also, entrepreneurial entry occurs if and only if* $c_2 < C_2^D(c_1, b)$*, so that significant process innovations result in entrepreneurship.*

Compare the innovator's incentive to invent to that of the incumbent monopolist when the invention consists of a new product design. The monopolist develops or adopts a new product design to diversify. With the initial process technology, the monopolists' incentive to develop a new product design is less than the benefit from adopting a new product design,

$$V^m = \Pi^m(c_1, c_1, b) - \Pi^m(c_1) < \Pi^m(c_1, c_1, b) - \Pi_1(c_1, c_2, b).$$

The innovator's incentive to invent the combination of a new product and a new process technology equals

$$(23) \quad V^I = \max\{\alpha(\Pi^m(c_1, c_1, b) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b), \Pi_2(c_1, c_2, b)\}.$$

This implies the following result.

PROPOSITION 8. *Consider the incentive to invent when only the new product design is transferable. When either the substitution parameter is less than the critical value* $b^D = b^D(c_1, c_2)$ *or greater than the critical value* $b^{DD} = b^{DD}(c_1, c_2)$, *or when the process innovation is significant,* $c_2 < C_2^D(c_1, b)$, *the innovator's incentive to invent is greater than that of an incumbent monopolist,* $V^I > V^m$.

5.5 The Strategic Innovation Game with an Independent Inventor and a Transferable Production Process

The discussion has so far assumed that the innovator must choose between technology transfer and entrepreneurship. Suppose instead that the inventor and the prospective entrepreneur are independent actors. The inventor can offer to license the process technology both to the existing firm and to an entrepreneur. The existing firm and the entrepreneurial entrant engage in differentiated products competition. The inventor chooses the royalty for the technology license but cannot otherwise choose which firm purchases the technology. There is no need to consider the choice of licensee because if the inventor could make such a choice, the outcome would be the same as the situation in which the inventor can become an entrepreneur, which was already considered in the previous section.

5.5.1 The Entrepreneur Does Not Have the Initial Technology

By selecting the amount of royalty to charge for the license, the inventor can affect the outcome of the adoption and entry game between the incumbent firm and the entrepreneur. The existing firm chooses whether or not to adopt the new process technology. Suppose first that the entrepreneur can only enter the market by adopting the new process technology so that the entrepreneur chooses between entry with adoption and not entering. This assumption will be relaxed later in the section by allowing the entrepreneur access to the initial process technology.

The strategic adoption and entry game has four possible outcomes. The existing firm chooses between continuing with the process initial technology and adopting the new process technology. The potential entrepreneur chooses whether or not to enter the market. Let R be the lump-sum royalty offered by the inventor. If both the incumbent and the entrepreneur

Table 5.1 **The technology adoption and entrepreneurship game with payoffs (existing firm 1, entrepreneurial firm 2)**

	Entrepreneurial firm 2	
Existing firm 1	Enter	Do not enter
Adopt	$\Pi_1(c_2, c_2, b) - R, \Pi_2(c_2, c_2, b) - R$	$\Pi^m(c_2) - R, 0$
Do not adopt	$\Pi_1(c_1, c_2, b), \Pi_2(c_1, c_2, b) - R$	$\Pi^m(c_1), 0$

adopt the new technology the payoffs are symmetric, $\Pi_1(c_2, c_2, b) - R$ and $\Pi_2(c_2, c_2, b) - R$. If only the entrepreneur adopts the new process technology, the payoffs are asymmetric, with the incumbent firm earning profits $\Pi_1(c_1, c_2, b)$ and the entrepreneur earning net returns $\Pi_2(c_1, c_2, b) - R$. If only the incumbent firm adopts the new process technology, the incumbent earns $\Pi^m(c_2) - R$ and the entrepreneur's payoff is zero. If neither firm adopts the new process technology, the incumbent firm earns $\Pi^m(c_1) - R$ and the entrepreneur's payoff again is zero. Table 5.1 shows the adoption-and-entry game.

Suppose that the inventor chooses royalties that are less than or equal to the incumbent's incremental returns from adoption when there is entrepreneurial entry,

$$R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b).$$

Then, the outcome (Adopt, Enter) is the unique equilibrium. To see why, first consider the incumbent firm's decisions. When $R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$, it follows that the incumbent firm will prefer to adopt the new technology as a best response to entry by the entrepreneur because

$$\Pi_1(c_2, c_2, b) - R \geq \Pi_1(c_1, c_2, b).$$

Since $c_2 < c_1$ and $\partial\Pi_1(c_1, c_2, b)/\partial c_1 < 0$, it follows that $\Pi_1(c_2, c_2, b) > \Pi_1(c_1, c_2, b)$ and $\Pi^m(c_2) > \Pi^m(c_1)$. Also, because $\partial^2\Pi_1(c_1, c_2, b)/\partial c_1\partial c_2 < 0$, for $c_2 < c_1$,

$$\Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b) \leq \Pi^m(c_2) - \Pi^m(c_1).$$

This implies $R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b) \leq \Pi^m(c_2) - \Pi^m(c_1)$, so that the incumbent firm will prefer to adopt the technology even if there is no entrepreneurial entry,

$$\Pi^m(c_2) - R \geq \Pi^m(c_1).$$

So, adoption is a dominant strategy for the incumbent firm.

Next, consider the decisions of the entrepreneur. If the incumbent firm adopts the technology and $R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$, it follows that $R \leq \Pi_1(c_1, c_2, b) = \Pi_2(c_2, c_2, b)$. The entrepreneur will adopt the technology and enter the market when the incumbent also adopts the technology. Because the entrepreneur earns greater profits when the incumbent does not adopt the technology, it follows that $R \leq \Pi_2(c_2, c_2, b) \leq \Pi_2(c_1, c_2, b)$. This implies that the entrepreneur also will choose to enter the market when the incumbent does not adopt the new technology. So, entry is a dominant strategy for the entrepreneur. Therefore, if $R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$, (Adopt, Enter) will be the unique dominant strategy equilibrium.

Now, we examine a monopoly inventor with market power who maximizes the returns from royalties. The adoption-entry game shows that if royalties induce adoption by the incumbent, they also induce entry by the entrepreneur. This is because $R \leq \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$ implies that $R \leq \Pi_1(c_2, c_2, b) = \Pi_2(c_2, c_2, b)$. The inventor earns royalties from both the incumbent and entrant by setting

$$R^* = \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b).$$

Alternatively, the inventor can raise the royalties to induce entry by the entrepreneur without adoption by the incumbent firm,

$$R^{**} = \Pi_2(c_1, c_2, b).$$

To see why the royalty that only induces adoption by the entrepreneur is greater, notice that $\partial^2\Pi_1(c_1, c_2, b)/\partial c_1 \partial c_2 < 0$ and $c_2 < c_1$ imply

$$\begin{aligned} R^* &= \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b) \\ &< \Pi_1(c_2, c_1, b) - \Pi_1(c_1, c_1, b) \\ &< \Pi_1(c_2, c_1, b) = \Pi_2(c_1, c_2, b) = R^{**}. \end{aligned}$$

The incumbent firm's profit when both adopt firms adopt the technology is less than industry profits when only the entrant adopts the technology,

$$\Pi_1(c_2, c_2, b) < \Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b).$$

The incumbent firm has less incentive to adopt the new process technology because of the inertia generated by the initial technology, as Arrow (1962) observed. The inventor chooses the lower royalty when he earns more from both firms adopting the innovation, $2R^*$, than from adoption by the entrepreneur, R^{**}. When $2R^* \geq R^{**}$, the independent inventor induces adoption by both firms, which differs from the possible outcomes when the inventor and the potential entrepreneur are not independent. The inventor chooses to transfer the technology to both the incumbent and the entrepreneur if and only if

$$\Pi_1(c_2, c_2, b) \geq \Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b)/2.$$

When $2R^* < R^{**}$, the independent inventor induces adoption by only the entrepreneur, which corresponds to the equilibrium with entry when the inventor and the potential entrepreneur are not independent.

The technology transfer decision of an independent inventor has the following important implication.

PROPOSITION 9. *When the inventor is independent and the entrepreneur does not have access to the initial process technology, entrepreneurship always takes place.*

When the inventor is independent from the entrepreneur, royalties that allow technology transfer to the incumbent firm always involve also selling to the entrepreneur. The entrepreneur values the process innovation more than the incumbent because of the inertia from the initial technology. Choosing greater royalties excludes the incumbent firm so that the inventor then sells only to the entrepreneur. This result provides an additional explanation for entrepreneurship as the mechanism for innovation. It further emphasizes Schumpeter's observation that entrepreneurs operate beside incumbent firms.

The independent inventor's incentive to invent equals $V^* = \max\{2R^*, R^{**}\}$. Proposition 10 shows that an independent inventor benefits from competition for licenses between the entrepreneur and the incumbent firm in the adoption-and-entry game.

PROPOSITION 10. *The independent inventor's incentive to invent, V^*, is greater than or equal to that of nonindependent innovator, V^I, if the nonindependent inventor has limited bargaining power, $\alpha \leq \alpha^{**}$, where*

$$\alpha^{**} = \frac{2(\Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)) - \Pi_2(c_1, c_2, b)}{\Pi^m(c_2) - \Pi_1(c_1, c_2, b) - \Pi_2(c_1, c_2, b)} \tag{24}$$

PROOF. The independent inventor's incentive to invent can be written as

$$V^* = \max\{2(\Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)), \Pi_2(c_1, c_2, b)\}.$$

The independent inventor can raise the royalties to induce entry by the entrepreneur without adoption by the incumbent firm and obtain R^{**}. This is equivalent to entry by the nonindependent innovator, which yields $\Pi_2(c_1, c_2, b)$. So, if $\Pi_2(c_1, c_2, b) \geq \Pi^m(c_2) - \Pi_1(c_1, c_2, b)$, it follows that

$$V^* \geq R^{**} = \Pi_2(c_1, c_2, b) = V^I.$$

Conversely, if $\Pi_2(c_1, c_2, b) < \Pi^m(c_2) - \Pi_1(c_1, c_2, b)$, then $V^* \geq 2R^* \geq V^I = \alpha(\Pi^m(c_2) - \Pi_1(c_1, c_2, b)) + (1-\alpha)\Pi_2(c_1, c_2, b)$ if $\alpha \leq \alpha^{**}$. ■

An independent inventor is at least as well off as a nonindependent inventor who prefers to become an entrepreneur regardless of his bargaining power. An independent inventor is at least as well off as a nonindependent inventor who prefers technology transfer but has a low bargaining power. The nonindependent inventor who prefers technology transfer and has a high bargaining power can be better off than the independent inventor because he can capture the monopoly rents from transferring the technology to the incumbent. This is possible if $\Pi^m(c_2) > 2\Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)$.

The independent inventor has a greater incentive to invent than the monopolist contemplating a process innovation if products are sufficiently differentiated. When only the process innovation is transferable, let b^* be the critical value of the product differentiation parameter such that industry profits increase with entry. From the definition of V^* and b^*, it follows that

$$V^* \geq \Pi_2(c_1, c_2, b) \geq \Pi^m(c_2) - \Pi_1(c_1, c_2, b) > \Pi^m(c_2) - \Pi^m(c_1) = V^m.$$

PROPOSITION 11. *The independent inventor has a greater incentive to invent, V^*, than that of the monopolist, V^m, if products are sufficiently differentiated,* $0 \leq b \leq b^*$.

The independent inventor can do better than the monopolist even if there is less product differentiation when there are returns to selling to both the incumbent and the potential entrepreneur.

5.5.2 The Entrepreneur Can Use the Initial Technology

Entrepreneurship with independent inventors does not require the potential entrepreneur's outside option to be zero. Suppose that both the incumbent and the entrant have access to the initial process technology. The entrepreneur can enter with the initial process technology that is available without cost or the entrepreneur can obtain the new process technology from the inventor. Then, both the incumbent and the entrant are subject to the same inertia. The payoffs of the adoption and entry game are symmetric, see table 5.2.

By symmetry, the inventor then sells to both the incumbent and the entrant and cannot exclude the incumbent. The innovator with market power will choose the lower royalty,

$$R^* = \Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b) = \Pi_2(c_2, c_2, b) - \Pi_2(c_1, c_2, b).$$

This implies that the technology adoption game has an unique dominant-strategy equilibrium. The equilibrium of the technology adoption game is for both the incumbent firm and the entrepreneur to adopt the new process technology.

Table 5.2 **The technology adoption game with payoffs (existing firm 1, entrepreneurial firm 2) when the initial process technology is available to both the incumbent firm and the entrepreneurial firm**

	Entrepreneurial firm 2	
Existing firm 1	Adopt	Do not adopt
Adopt	$\Pi_1(c_2, c_2, b) - R, \Pi_2(c_2, c_2, b) - R$	$\Pi_1(c_2, c_1, b) - R, \Pi_2(c_2, c_1, b)$
Do not adopt	$\Pi_1(c_1, c_2, b), \Pi_2(c_1, c_2, b) - R$	$\Pi_1(c_1, c_1, b), \Pi_2(c_1, c_1, b)$

Proposition 12. *When the inventor is independent and the initial process technology is available to both the incumbent firm and the entrepreneur, the inventor transfers the process technology to both the incumbent and the entrepreneur.*

5.6 Conclusion

Multidimensional innovation, with new product designs and new production processes, illustrates Schumpeter's assertion that entrepreneurs make "new combinations." The discussion extends Arrow (1962), which classifies a process innovation as being drastic or nondrastic depending upon whether the monopoly price with the new production technology is less than or greater than the unit costs under the old technology. Multidimensional innovation implies that the extent of an innovation depends both on the degree of product differentiation and on changes in production costs. The new product design and the new production process interact in an interesting way. The degree of product differentiation between the new and the existing product helps to determine the critical threshold that defines a significant process innovation. The extent of multidimensional innovation is important because it affects both the returns to technology transfer and the returns to entrepreneurial entry.

The present multidimensional innovation model provides a compelling explanation for why entrepreneurship occurs in established industries. By mitigating competition, product differentiation generates rents for entrepreneurial entrants. These rents allow innovators to pursue entrepreneurship as a profitable alternative to transferring technology to incumbent firms. By making entrepreneurship a viable option for innovators, product differentiation also means that the incumbent firm must consider how entrepreneurial entry will affect its profits. With sufficient product differentiation, industry profits with entrepreneurial entry are greater than monopoly profits for an incumbent firm. Equivalently, the returns to technology transfer from the innovator to the incumbent firm will then be less than the returns to entrepreneurial entry. When this occurs, entrepreneurship is the equilibrium outcome of the innovation game. Product differentiation sheds light on Schumpeter's concept of "creative destruction," with innovative entrepreneurs operating beside existing firms.

Transaction costs and other impediments to the transfer of discoveries make entrepreneurship a potential outcome of the innovation game. When new products and processes are fully transferable to the existing firm, entrepreneurship will not take place. However, imperfect transferability generates incentives for innovators to become entrepreneurs. When the incumbent firm can buy out the innovator but neither the new product nor the new production technology is transferable, entrepreneurship occurs when process innovations are significant. This effect is reversed when only the process innovation is transferable; incremental process innovations lead the innovator to choose entrepreneurship and significant innovations lead the innovator to transfer the technology to the incumbent firm. When only the product innovation is transferable, significant process innovations lead the innovator to choose entrepreneurship and incremental process innovations lead the innovator to transfer the technology to the incumbent firm.

The discussion extends the strategic innovation game to allow an independent inventor. The existing firm and the entrepreneurial entrant engage in differentiated-products competition. The inventor has the option of transferring the process technology to the existing firm, the entrepreneur, or to both. The inventor chooses royalties such that the existing firm and the entrepreneur decide whether or not to adopt the process technology, and entrepreneurship always occurs in equilibrium. The inventor benefits from competition between the existing firm and the entrepreneurial entrant.

The present analysis took inventions as given, following Arrow's (1962) approach. However, the model can be generalized to include endogenous R&D. Economic factors that encourage or discourage entrepreneurship will impact invention and the choice between technology transfer and entrepreneurial entry. In addition, economic factors that affect the costs of technology transfer will affect incentives to invent and the types of firms that implement innovations. Public policies such as business taxes and regulations that discourage entrepreneurship block a significant channel of innovation. Imperfect legal protections for IP that allow expropriation and imitation are likely to discourage technology transfer and encourage entrepreneurship.

Entrepreneurship stimulates inventive activity in established industries by opening multiple avenues for innovation. Innovators can commercialize inventions not only through technology transfer but also though entrepreneurship or by licensing to independent entrepreneurs. The present analysis identified conditions under which an innovator who chooses between technology transfer and entrepreneurship has a greater incentive to invent than an incumbent monopolist. This is consistent with the observed close association between innovation and entrepreneurship. Together, technology transfer to incumbents and the establishment of new firms increase the total returns to inventive activity. The outcome of the strategic innovation game and the transferability of technology also affect the mix of new products and new production processes that are commercialized. By embodying innovations in new firms, entrepreneurs profoundly influence the rate and direction of inventive activity.

References

Acs, Z. J., and D. B. Audretsch. 1988. "Innovation in Large and Small Firms: An Empirical Analysis." *American Economic Review* 78 (4): 678–90.

Acs, Z. J., D. B. Audretsch, P. Braunerhjelm, and B. Carlsson. 2004. "The Missing Link: The Knowledge Filter and Entrepreneurship in Economic Growth." Center for Economic and Policy Research. CEPR Working Paper no. 4358.

Anand, B., and T. Khanna. 2000. "The Structure of Licensing Contracts." *Journal of Industrial Economics* 48 (1): 103–35.

Anton, J. J., and D. A. Yao. 1994. "Expropriation and Inventions." *American Economic Review* 84:190–209.

———. 2003. "Patents, Invalidity, and the Strategic Transmission of Enabling Information." *Journal of Economics & Management Strategy* 12:151–78.

Arora, A., A. Fosfuri, and A. Gambardella. 2001a. *Markets for Technology: The Economics of Innovation and Corporate Strategy.* Cambridge, MA: MIT Press.

———. 2001b. "Specialized Technology Suppliers, International Spillovers and Investment: Evidence from the Chemical Industry." *Journal of Development Economics* 65:31–54.

Arora, A., and A. Gambardella. 1998. "Evolution of Industry Structure in the Chemical Industry." In *Chemicals and Long-Term Economic Growth,* edited by A. Arora and N. Rosenberg, 379–414. New York: Wiley.

Arrow, K. J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 609–626. Princeton, NJ: Princeton University Press.

Audretsch, D. B. 1995a. *Innovation and Industry Evolution.* Cambridge, MA: MIT Press.

———. 1995b. "Innovation, Growth and Survival: The Post-Entry Performance of Firms." *International Journal of Industrial Organization* 13 (4): 441–57.

———. 2001. "The Role of Small Firms in U.S. Biotechnology Clusters." *Small Business Economics* 17:3–15.

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

Balconi, M., A. Pozzali, and R. Viale. 2007. "The 'Codification Debate' Revisited: A Conceptual Framework to Analyze the Role of Tacit Knowledge in Economics." *Industrial and Corporate Change* 16 (5): 823–49.

Baumol, W. J. 1968. "Entrepreneurship in Economic Theory." *American Economic Review Papers and Proceedings* 58:64–71.

———. 1993. *Entrepreneurship, Management, and the Structure of Payoffs.* Cambridge, MA: MIT Press.

———. 2002. *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism.* Princeton, NJ: Princeton University Press.

———. "Entrepreneurship and Invention: Toward Their Microeconomic Value Theory." Special Session on Entrepreneurship, Innovation and Growth I: Theoretical Approach, American Economic Association Meetings.

Baumol, W. J., R. E. Litan, and C. J. Schramm. 2007. *Good Capitalism, Bad Capitalism, and the Economics of Growth and Properity.* New Haven, CT: Yale University Press.

Blonigen, B. A., and C. T. Taylor. 2000. "R&D Activity and Acquisitions in High Technology Industries: Evidence from the US electronics Industry." *Journal of Industrial Economics* 48:47–70.

Bresnahan, T. F., and D. M. G. Raff. 1991. "Intra-Industry Heterogeneity and the Great Depression: The American Motor Vehicles Industry, 1929–1935." *Journal of Economic History* 51:317–31.

Bresnahan, T. F., S. Greenstein, and R. M. Henderson. 2012. "Schumpeterian Competition and Diseconomies of Scope: Illustrations from the Histories of Microsoft

and IBM." In *The Rate and Direction of Inventive Activity Revisited,* edited by Josh Lerner and Scott Stern, 203–76. Chicago: University of Chicago Press.
Chandler, A. D. 1990. *Scale and Scope: The Dynamics of Industrial Capitalism.* Cambridge, MA: Harvard University Press.
Chen, Y., and M. Schwartz. 2009. "Product Innovation Incentives: Monopoly vs. Competition." University of Colorado. Working Paper.
Christensen, C. M. 1997. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail.* Boston: Harvard Business School Press.
Danaher, P. J., I. W. Wilson, and R. A. Davis. 2003. "A Comparison of Online and Offline Consumer Brand Loyalty." *Marketing Science* 22 (4): 461–76.
Fein, A. J. 1998. "Understanding Evolutionary Processes in Non-Manufacturing Industries: Empirical Insights from the Shakeout in Pharmaceutical Wholesaling." *Journal of Evolutionary Economics* 8:231–70.
Furman, J. L., and M. MacGarvie. 2009. "Academic Collaboration and Organizational Innovation: The Development of Research Capabilities in the US Pharmaceutical Industry, 1927–1946." *Industrial and Corporate Change* 18 (5): 929–61.
Galambos, L., and J. L. Sturchio. 1998. "Pharmaceutical Firms and the Transition to Biotechnology: A Study in Strategic Innovation." *Business History Review* 72 (2): 250–78.
Gans, J. S., D. H. Hsu, and S. Stern. 2000. "When Does Start-Up Innovation Spur the Gale of Creative Destruction?" *Rand Journal of Economics* 33:571–86.
Gans, J. S., and S. Stern. 2000. "Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction." *Journal of Economics & Management Strategy* 9:485–511.
———. 2003. "The Product Market and the Market for 'Ideas': Commercialization Strategies for Technology Entrepreneurs." *Research Policy* 32:333–50.
Giarratana, M. S. 2004. "The Birth of a New Industry: Entry by Start-ups and the Drivers of Firm Growth: The Case of Encryption Software." *Research Policy* 33 (5): 787–806.
Gilbert, R. 2006. "Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?" *Innovation Policy and the Economy,* Vol. 6, edited by Adam B. Jaffe, Josh Lerner, and Scott Stern, 159–215. Cambridge, MA: MIT Press.
Gilbert, R., and D. Newbery. 1982. "Preemptive Patenting and the Persistence of Monopoly." *American Economic Review* 72:514–26.
Greenstein, S. and G. Ramey. 1998. "Market Structure, Innovation and Vertical Product Differentiation." *International Journal of Industrial Organization* 16 (3): 285–311.
Grindley, P. C., and D. J. Teece. 1997. "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics." *California Management Review* 39:8–41.
Henderson, R. 1993. "Underinvestment and Incompetence as Responses to Radical Innovation—Evidence from the Photolithographic Alignment Equipment Industry." *Rand Journal of Economics* 24 (2): 248–70.
Henderson, R., and K. Clark. 1990. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." *Administrative Science Quarterly* 35:9–30.
Hotelling, H. 1929. "Stability in Competition." *Economic Journal* 39 (153): 41–57.
Kato, A. 2007. "Chronology of Lithography Milestones Version 0.9." Available at: http://www.lithoguru.com/scientist/litho_history/Kato_Litho_History.pdf.
Katz, M. L., and C. Shapiro. 1987. "R&D Rivalry with Licensing or Imitation." *American Economic Review* 77:402–20.
Kienle, H., D. German, S. Tilley, and H. A. Muller. 2004. "Intellectual Property Aspects of Web Publishing." In *ACM Special Interest Group for Design of Com-*

munication, Proceedings of the 22nd Annual International Conference on Design of Communication: The Engineering of Quality Documentation, 136–144. New York: Association for Computing Machinery.

Kimes, B. R., and H. A. Clark. 1996. *Standard Catalog of American Cars 1805 to 1942,* 3rd ed. Iola, WI: Krause Publications.

Klette, T. J., and S. Kortum. 2004. "Innovating Firms and Aggregate Innovation." *Journal of Political Economy* 112 (5): 986–1018.

Kline, S. J., and N. Rosenberg. 1986. "An Overview of Innovation." In *The Positive Sum Strategy: Harnessing Technology for Economic Growth,* edited by R. Landau and N. Rosenberg, 275–306. Washington, DC: National Academy Press.

Lowe, R., and A. Ziedonis. 2006. "Overoptimism and the Performance of Entrepreneurial Firms." *Management Science* 52 (2): 173–186.

Lucking-Reiley, D., and D. F. Spulber. 2001. "Business-to-Business Electronic Commerce." *Journal of Economic Perspectives* 15:55–68.

Maney, K. 1995. *Megamedia Shakeout: The Inside Story of the Leaders and the Losers in the Exploding Communications Industry.* New York: Wiley.

McClellan, S. T. 1984. *The Coming Computer Industry Shakeout: Winners, Losers, and Survivors.* New York: Wiley.

Milgrom, P., and J. Roberts. 1990. "Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities." *Econometrica* 58 (6): 1255–77.

Morrison, S. A., and C. Winston. 1995. *The Evolution of the Airline Industry.* Washington, DC: Brookings Institution.

O'Shea, R., T. Allen, A. Chevalier, and F. Roche. 2005. "Entrepreneurial Orientation, Technology Transfer and Spinoff Performance of U.S. Universities." *Research Policy* 34 (7): 994–1009.

Peterson, B. S., and J. Glab. 1994. *Rapid Descent: Deregulation and the Shakeout in the Airlines.* New York: Simon and Schuster.

Prevezer, M. 1997. "The Dynamics of Industrial Clustering in Biotechnology." *Small Business Economics* 9 (3): 255–71.

Rasmusen, E. 1988. "Entry for Buyout." *Journal of Industrial Economics* 36 (3): 281–99.

Reinganum, J. F. 1981. "Dynamic Games of Innovation." *Journal of Economic Theory* 25:1–41.

———. 1982. "A Dynamic Game of R and D: Patent Protection and Competitive Behavior." *Econometrica* 50:671–88.

———. "The Timing of Innovation: Research, Development, and Diffusion." In *Handbook of Industrial Organization,* Vol. 1, edited by R. Schmalensee and R. D. Willig, 849–908. New York: Elsevier Science Publishers.

Salant, S. W. 1984. "Preemptive Patenting and the Persistence of Monopoly: Comment." *American Economic Review* 74:247–50.

Say, J.-B. (1841) 1982. *Traité d'Économie Politique,* 6th ed. Geneva: Slatkine.

———. 1852. *Cours Complet d'Économie Politique: Pratique,* Vols. 1 and 2, 3rd ed. Paris: Guillaumin et Ce.

Schramm, C. J. 2006. *The Entrepreneurial Imperative: How American's Economic Miracle Will Reshape the World (and Change Your Life).* New York: HarperCollins.

Schumpeter, J. A. (1934) 1997. *The Theory of Economic Development.* New Brunswick, NJ: Transaction Publishers.

———. (1964) 1989 *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process,* (abridged version of first edition published in 1939). Philadelphia: Porcupine Press.

Singh, N., and X. Vives. 1984. "Price and Quantity Competition in a Differential Duopoly." *Rand Journal of Economics* 15:546–54.

Spulber, D. F. 2009. *The Theory of the Firm: Microeconomics with Endogenous Entrepreneurs, Firms, Markets, and Organizations.* Cambridge: Cambridge University Press.
———. 2010. "Tacit Knowledge with Innovation and Entrepreneurship." Northwestern University. Working Paper.
———. "The Innovator's Decision: Entrepreneurship versus Technology Transfer." In *Handbook of Research on Innovation and Entrepreneurship,* edited by D. Audretsch, O. Falck, S. Heblich, and A. Lederer. Northampton, MA: Edward Elgar.
Teece, D. J. 1986. "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy." *Research Policy* 15:285–305.
———. 2006. "Reflections on 'Profiting from Innovation'." *Research Policy* 35: 1131–46.
Tilton, J. E. 1971. *International Diffusion of Technology: The Case of Semiconductors.* Washington, DC: Brookings Institution.
Torrisi, S. 1998. *Industrial Organisation and Innovation: An International Study of the Software Industry.* Cheltenham, UK: Edward Elgar Publishing.
Vohora, A., M. Wright, and A. Lockett. 2004. "Critical Junctures in The Development of University High-Tech Spinout Companies." *Research Policy* 33:147–75.
Winter, S. G. 1984. "Schumpeterian Competition in Alternative Technological Regimes." *Journal of Economic Behavior and Organization* 5 (3–4): 287–320.
Zanchettin, P. 2006. "Differentiated Duopoly with Asymmetric Costs." *Journal of Economics & Management Strategy* 15 (4): 999–1015.
Zucker, L., M. Darby, and J. Armstrong. 1998. "Geographically Localized Knowledge: Spillovers or Markets?" *Economic Inquiry* 36:65–86.
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.

Comment Luis Cabral

Let me start by saying that I enjoyed reading the chapter.

Instead of going through the details of the chapter, I thought it might be more useful to put the main results into perspective, mainly in terms of the Industrial Organization (IO) literature on innovation. Moreover, I would like to take a further step back and talk about several literatures that I think are related to this chapter (although that link has not always been explored as much as it should):

- The literature on innovation, invention, adoption, and so forth
- The productivity literature
- The literature on entry and entrepreneurship

Traditionally, the productivity literature has been largely concerned with measurement issues. The entry and entrepreneurship literature in turn has

Luis Cabral is professor of economics at the Stern School of Business, New York University.