How Entrepreneurs Affect the Rate and Direction of Inventive Activity

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Abstract

Entrepreneurship in established industries poses a puzzle. Entrepreneurial entry increases competition, which suggests that innovators will earn greater returns simply by transferring their technology to incumbent firms. The paper presents a strategic innovation game in which an innovator and an established firm choose whether to cooperate or to compete. The main result of the analysis is that with sufficient product differentiation, the equilibrium outcome is entrepreneurship rather than technology transfer. Product differentiation increases the returns to entrepreneurship relative to the returns from technology transfer. Second, with sufficiently differentiated products, an innovator who can choose between licensing the innovation to the incumbent and becoming an entrepreneur has a greater incentive to invent than an incumbent monopolist. Third, when an independent inventor is an additional player in the strategic game, the market equilibrium always involves entrepreneurial entry. Fourth, with sufficiently differentiated products, an independent innovator has a greater incentive to invent than an incumbent monopolist.

JEL codes: L1, L26, O3

1.   Introduction

Entrepreneurship poses a challenge to researchers and policy makers: *why does entrepreneurial entry occur in established industries?* Creative destruction by entrepreneurs requires costly market entry and rent dissipation from competition with existing firms. Technology transfer allows for innovation without the costs of creative destruction. Creative destruction thus gives innovators and existing firms an incentive to cooperate through technology transfer. 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 creative destruction. The mix of entrepreneurship and contracting depends on the transferability of product and process innovations. Innovators affect the rate and direction of inventive activity by either 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. Technology transfer is limited by difficulties in transferring one or the other aspect of the 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 insight 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 major innovations favor technology transfer. Greater product differentiation gives innovators greater incentives to invent that 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 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 innovator 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 technology to an entrepreneur. This provides another answer to the challenge of entrepreneurship: due to strategic interaction independent innovators 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 et al. (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 assumes homogeneous products and shows 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 et al (2006), Acs et al. (2004), Schramm (2006), and Baumol et al. (2007). Schumpeter emphasizes that entrepreneurs provide a large share of the technological innovations that stimulate the growth and development of capitalist economies. As Schumpeter (1934, p. 66) points out, entrepreneurship involves the carrying out of new combinations, which includes 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. Schumpeter (1934, p. 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

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[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.

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.

The paper is organized as follows. Section 2 presents the game of strategic innovation played by an innovator and an incumbent firm. Section 3 considers equilibrium outcome of the strategic innovation game. Section 4 considers the strategic innovation game with imperfect legal protections for IP that allow expropriation and imitation. The analysis shows that when there is limited protection for intellectual property and the innovator faces a risk of expropriation, entrepreneurship becomes more likely. Section 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 6 concludes the discussion.

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, transactions, and businesses 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 startups. 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 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.

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 individual 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 startup firms licensed 36% of the inventions and existing firms licensed the remainder. The study implicitly provides evidence of the choice between licensing to a startup and licensing to an incumbent because over 75% of inventions licensed to startups 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,"

(p. 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," p. 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 do 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 et al. (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 et al., 2004, p. 156). Vohora et al. (2004, p. 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 route 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 startups carried out most of the initial stages of applied research in recombinant DNA technology and molecular genetics (Galambos and Sturchio, 1998). In the U.S. biotech, about 5,000 small and startup 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, p. 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 to 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 entreprenerial 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 startups 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 startups to existing firms. Even when existing firms have substantial in-house R&D capabilities, they often rely on independent inventors, partners, and startups for technology transfers. Arora et al (2001a) consider the incentives of startups to license their technology. Arora et al. (2001a, b) consider 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 startups by established firms in the U.S. 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 (v Torrisi, 1998), including for example encryption software Giarratana (2004).

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[2] Bresnahan and Raff (1991) examine intra-industry 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 startups and established firms, see Henderson and Clark (1990) and Christensen (1997).

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' establishment of Amazon.com involved launching a new brand, introducing new business methods, and 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-morter" 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, p. 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, p. 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."

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

Kline and Rosenberg (1986, p. 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 frictionless 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 can 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* which 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 et al. (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 also is 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 also can 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).

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 what distinguishes the existing product from the new product. The differences between the existing product and the new product may be fundamental differences in features. The

products may be differentiated horizontally, such as Coke and Diet Coke, or the products can be differentiated vertically, such as Toyota and Lexus.

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 product. This entails costs of establishing the new division 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 et al. 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 bricks-and-mortar retailer. This is important for our analysis, which considers the possibility that new products are not transferable to the 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. This approach returns the analysis to the equivalent of a single-product setting.

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. Klete 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. Our analysis innovators who choose between entrepreneurship and technology transfer have greater incentives to develop new products and new processes than incumbent monopolists.

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 innovator and the incumbent monopolist must choose between competition and cooperation. If the innovator and the existing firm cooperate, the innovator can transfer some aspect of the invention to an existing firm. Alternatively, the innovator can enter the market by becoming an entrepreneur and employing the new discovery, introducing both the new product design and the new production process. If the innovator establishes a firm, the incumbent and the entrant engage in Bertrand-Nash competition.

3.1 Technology Transfer

Due to various transaction costs, the invention may be imperfectly transferable. Ruling out the uninteresting case in which the invention cannot be transferred at all, there are three possibilities: both the product design and the production process are transferable, the product design is transferable and the production process is not transferable, and the product design is not transferable and the production process is 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.

If the innovator becomes an entrepreneur, designate the new firm as firm 2. Let q_1 be the output of firm 1 and q_2 the output of firm 2. 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

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

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 $\partial D_i(p_1, p_2; b)/\partial p_j > 0$, $i \neq j$, $i, j = 1, 2$. Also, demand is decreasing in the substitution parameter, $\partial D_i(p_1, p_2; b)/\partial b < 0$, because $\dfrac{\partial D_i(p_1, p_2; b)}{\partial b} = -(1 - b^2)q_j, \qquad i \neq j, i, j = 1, 2.$

The existing firm is designated as firm 1 and is initially a single-product monopolist. The existing firm's initial technology is represented by unit cost c_1. For ease of presentation, assume that the new technology, c_2, is superior to the existing technology, $c_1 > c_2$. 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 technology to deter entry without applying the new technology.

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

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

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.

The profit of a two-product monopolist is given by

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

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

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

Using the envelope theorem, the two-product monopolist's profit is decreasing in the substitution parameter, $\dfrac{\partial \Pi^m(c_1, c_2; b)}{\partial b} = \sum_{i=1}^{2} (p_i - c_i) \dfrac{\partial D_i(p_1, p_2; b)}{\partial b} < 0$.

3.2   Entrepreneurial entry

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. The products of the existing firm and the entrant are differentiated. 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

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

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

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

When duopoly output levels are positive they equal

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

The profits of the firms are

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

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 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, $p_2^L(c_1, c_2) = (1/b)[c_1 - 2(1 - b)] < p^m(c_2) = 1 + c_2/2$. 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. Also, note that the results of the following analysis do not require price competition. The results can be restated with the two firms engaging in Cournot quantity competition with differentiated products.

4. Equilibrium of the Strategic Innovation Game

Consider the incumbent firm's returns to technology transfer from the innovator to the existing firm when the new technology is superior to that of the incumbent firm, $c_2 < c_1$. There are four possibilities. If both the new product design and the new production process are transferable, then the existing firm obtains profit from producing both goods using the new technology, $\Pi^m(c_2, c_2; b)$. If the new product design is transferable but the new production process is not transferable, then the existing firm obtains profit from producing both goods using the initial technology, $\Pi^m(c_1, c_1; b)$. If the new product design is not transferable and the new production process is transferable, then the existing firm obtains profit $\Pi^m(c_2)$. Finally, if neither the new product design nor the production technology are transferable, the existing firm still can license the new technology as a means of deterrring entry so that the existing firm's payoff is its initial profit, $\Pi^m(c_1)$.

4.1 Fully Transferable Technology versus Non-Transferable Technology

Total profits are continuous in the new process technology c_2 and have 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 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

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

Finally, for incremental innovations, $c_2^{0}(c_1, b) < c_2 < c_1$, both firms operate and industry profits are decreasing and convex in c_2. For all $b < 1$, industry profits reach a minimum at

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

With fully transferable technology, the returns to cooperation exceed the returns to competition. 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 the duopoly profits, $\Pi_2(c_1, c_2, b)$. With full technology transfer, the monopolist with the new product design and the new production process earns more than industry profits with entrepreneurial entry for all b,

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

This holds because of the 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 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.

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 a 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 efficiently 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

$$R = \alpha(\Pi^m(c_2, c_2, b) - \Pi_1(c_1, c_2, b)) + (1 - \alpha)\Pi_2(c_1, c_2, b).$$

Suppose in contrast, that neither the new product design nor the new production process is transferable. The innovator can still contract with the existing firm in return 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 would continue to operate as a single-product monopoly with profits, $\Pi^m(c_1)$. The lowest value of profits $\Pi_1(c_1, c_1, b) + \Pi_2(c_1, c_1, b)$ is greater than, equal to, or less than $\Pi^m(c_1)$ depending on the substitution parameter. Entrepreneurial entry need not always occur because the innovator and the existing firm still have incentives to avoid competition.

Entrepreneurial entry occurs if and only if the substitution parameter is either above or below an intermediate range, see Figure 1. 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. For a given degree of product differentiation, entrepreneurial entry occurs is the innovation is incremental. With significant innovations, the incumbent and the entrant have greater incentives to cooperate to avoid creative destruction, see Figure 2.

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[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.

<u>Proposition 2.</u> With non-transferable 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 $b^{NN} = b^{NN}(c_1, c_2)$. Also, with non-transferable technology, entrepreneurial entry occurs if and only if costs are greater than the critical value, $C_2^N(b, c_1) \leq 1$.

<u>Proof.</u> 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

(11)
$$b^0 = \frac{-(2-c_2)+[(2-c_2)^2+8(2-c_1)^2]^{1/2}}{2(2-c_1)}.$$

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

(12)
$$b^{00} = \frac{2(2-c_1)}{2-c_2}.$$

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

(13)
$$\Pi_1(c_1,c_2,b)+\Pi_2(c_1,c_2,b) = \frac{(4-5b^2+b^4)A-(4b-2b^3)B}{(1-b^2)(4-b^2)^2},$$

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 equal

(14)
$$\Pi_1(c_1,c_2,b)+\Pi_2(c_1,c_2,b) = \Pi_2^L(c_1,c_2,b) = \frac{(2-c_1)[b(2-c_2)-(2-c_1)]}{b^2}.$$

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 (14),

(15)
$$\Pi_1(c_1,c_2,b^0)+\Pi_2(c_1,c_2,b^0) = \frac{(2-c_2)^2[1-(b^0)^2]}{[2-(b^0)^2]^2} = \Pi_2^L(c_1,c_2,b^0).$$

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

(16)
$$\Pi_2^L(c_1,c_2,b^{00}) = \frac{(2-c_2)^2}{4} = \Pi^m(c_2).$$

For $0 \leq b < b^0$, the industry profits function in equation (13) 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 $0 \leq b < 1$. If $(4 - 9b^2 + 2b^4 - b^6) \leq 0$ 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 $b^0 \leq b \leq b^{00}$, $\Pi_2^L(c_1,c_2,b)$ 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

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

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 $0 \leq b < b^N(c_1, c_2)$ or $b^{NN}(c_1, c_2) \leq b < 1$. 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 are greater than the critical value, $C_2^N(b, c_1) \leq 1$. ∎
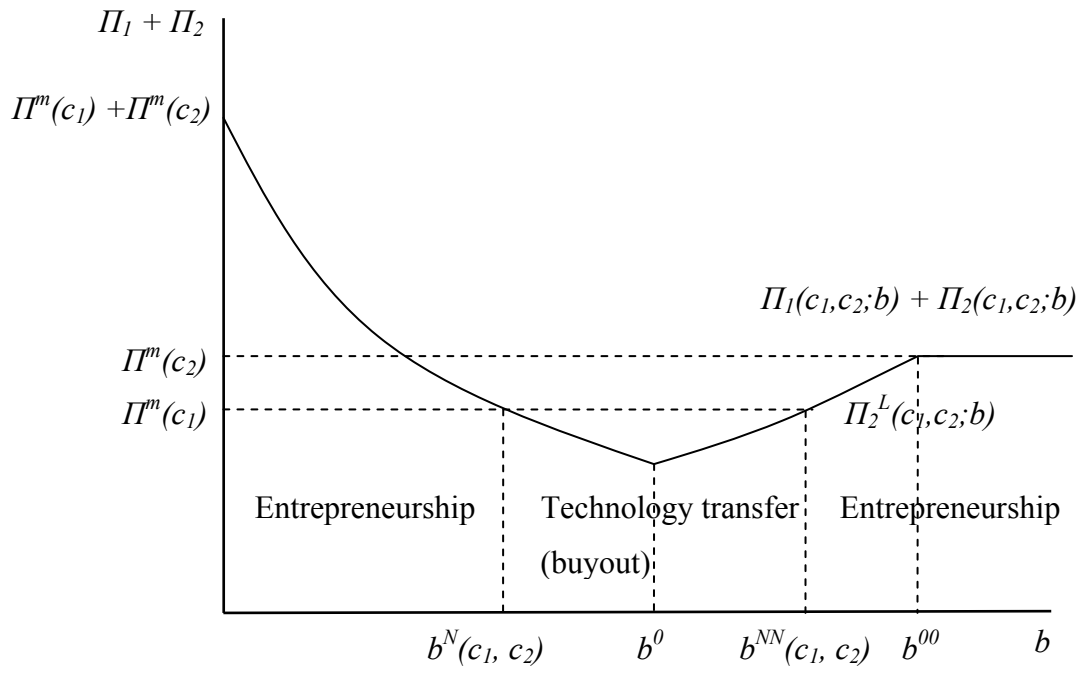
Figure 1   The outcome of the innovation game is entrepreneurship if and only if the substitution parameter is less than the critical value $b^N = b^N(c_1, c_2)$ or greater than the critical value $b^{NN} = b^{NN}(c_1, c_2)$.
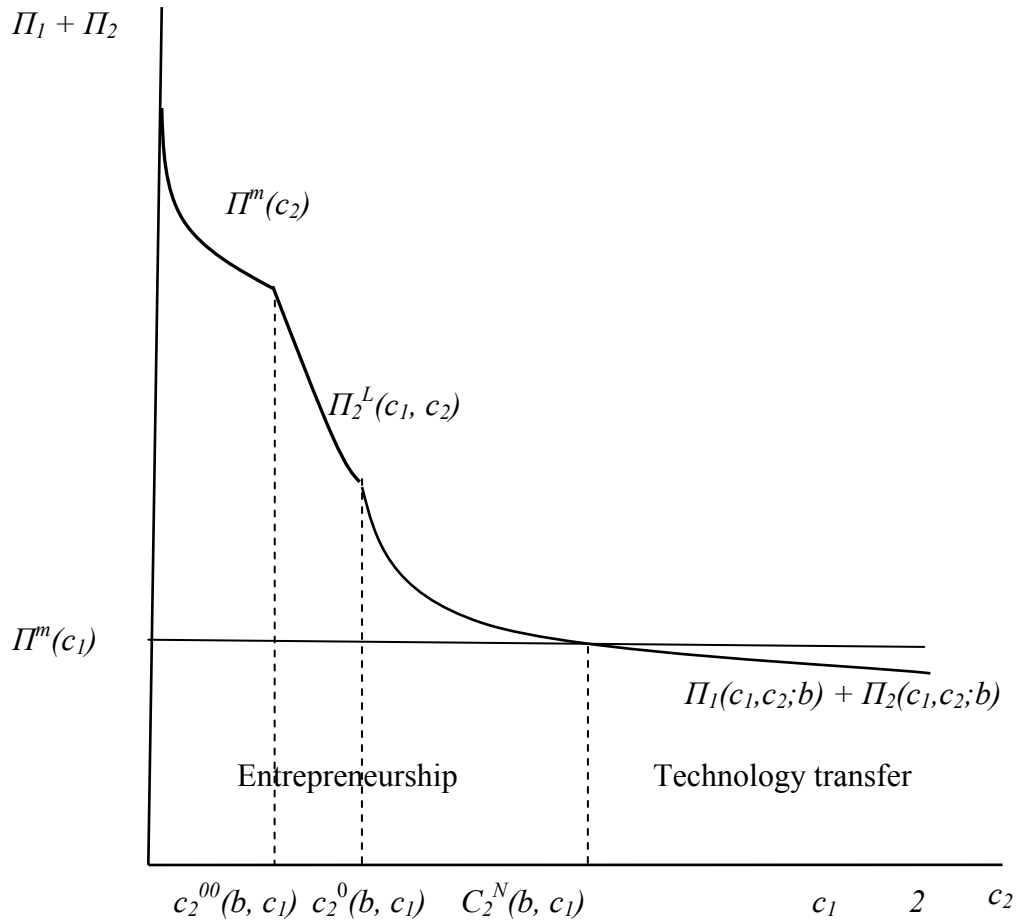
Figure 2   With non-transferable technology, the outcome of the innovation game is entrepreneurship if and only the new process costs are greater than the critical value, $C_2^N(b, c_1) \leq 1$.

4.2   The New Production Process is Transferable

Suppose that the new production process is transferable but the new product design is not. If the innovator and the incumbent firm choose to cooperate, the incumbent firm is a single-product monopolist with a new production technology, and earns profits $\Pi^m(c_2)$. 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 the 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, $\Pi^m(c_2) - \Pi_1(c_1, c_2, b)$. 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 or equal to monopoly profit at the new technology,

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

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 who then will use it in production of a new good.

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 is the difference between costs with the new technology and costs with the initial technology, the higher is the quality of the process innovation. The following result shows that technology transfer is associated with significant process inventions while entrepreneurship is associated with incremental process inventions. This result further explains Schumpeter's assertion that the entrepreneur establishes a firm beside the existing firm. With incremental improvements in technology, creative destruction occurs

at the margin. The innovator uses incremental technological change to offer a new product that competes with the incumbent firm. With significant improvements in 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.

Product differentiation makes entrepreneurial entry possible even when the innovator has the option of technology transfer. 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 which 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 c_2^*, where $c_2^0(c_1, b) < c_2^*(c_1, b) \leq c_1$, such that

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

When the process innovation is significant, industry profits with competition are less than or equal 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 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. This result helps to explain why entrepreneurial entry can occur in waves with entrants introducing incremental process innovations.

This establishes the main result.

<u>Proposition 3</u>. With a transferable production process, the following hold.
(i) Entrepreneurial entry will take place if and only 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. (ii) There exists a critical value of the new technology, $0 < c_2^*(c_1, b) \leq c_1$, such that entrepreneurship occurs in equilibrium when the process innovation is incremental, $c_2 > c_2^*(c_1, b)$. The threshold is greater than that for limit pricing, $c_2^*(c_1, b) > c_2^0(c_1, b)$.

Sufficient product differentiation mitigates competition so that industry profits are greater than monopoly profits using the new production technology. When products are sufficiently differentiated, the innovator obtains greater returns from entrepreneurship than from technology transfer. If products are not sufficiently differentiated, the innovator and the incumbent firm cooperate and transfer the production technology.

Proposition 3 confirms Schumpeter's assertion that the entrepreneur will enter beside the existing firm. Even if the innovator has the option of transferring the technology to the incumbent, the innovator will choose entrepreneurship when product differentiation attenuates competition in the product market. When product differentiation limits product market competition, entrepreneurship takes place whether or not the new technology improves on the incumbent's technology. Low values of the substitution parameter reduce competition after entry and therefore reduce incentives for cooperation between the incumbent and the innovator. High values of the substitution parameter indicate vigorous competition with entrepreneurial entry. This provides incentives for the

incumbent to buy out an equivalent or inferior technology or to adopt a superior technology.

Entrepreneurial entry with process innovations is closely tied to differentiated products. When consumers benefit from product variety, innovators with new production processes become entrepreneurs and provide new products to the market. Innovators with incremental technologies will embody their innovations in new firms. Transaction costs in the market for technology transfer enhance these effects. When the innovator and the incumbent firm would encounter transaction costs, innovators are more likely to become entrepreneurs. When there is intense competition in the product market or when innovators have major innovations, it follows that entrepreneurship requires some form of transaction costs in the technology transfer market.

Entrepreneurial entry with process innovations is closely tied to differentiated products. When consumers benefit from product variety, innovators with new production processes become entrepreneurs and provide new products to the market. Innovators with incremental technologies will embody their innovations in new firms. Transaction costs in the market for technology transfer enhance these effects. When the innovator and the incumbent firm would encounter transaction costs, innovators are more likely to become entrepreneurs. When there is intense competition in the product market or when innovators have major innovations, it follows that entrepreneurship requires some form of transaction costs in the technology transfer market. Because the industry profits function is decreasing in the substitution parameter when both firms operate profitably, the cost threshold in Proposition 2, $c_2*(b, c_1)$, is increasing in the substitution parameter. This implies that with greater product substitutability, that is with lower values of b, the range of innovations that result in entrepreneurship increases.

Corollary 1. With greater product substitutability, entrepreneurs enter the market with more significant innovations.
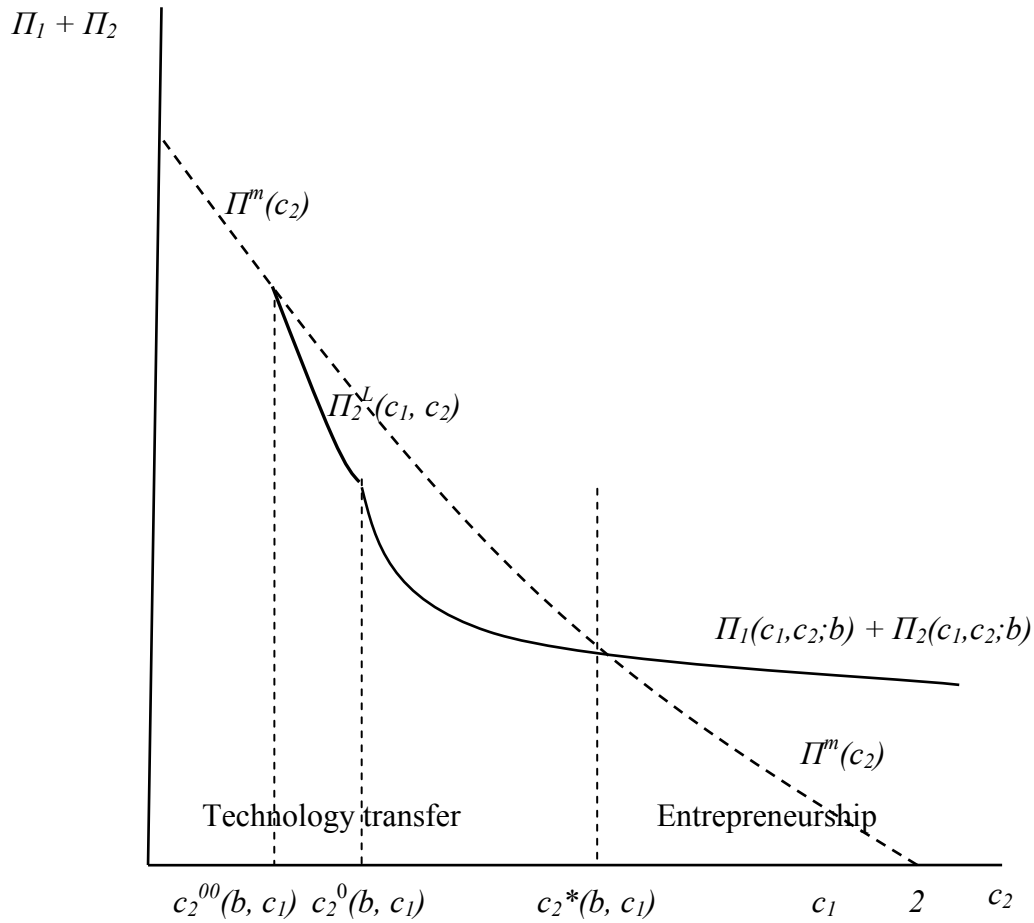
Figure 3   The outcome of the innovation game is entrepreneurship if and only if the new process technology is incremental, $c_2 > c_2^*(c_1, b)$.

Proposition 3 yields insights into Arrow's original investigation of the incentive to invent. Compare the innovator's incentive to invent to that of the incumbent monopolist when the invention consists of a new process technology. The incumbent monopolist's incentive to invent equals the difference between profits with the new technology and profits with the old technology,

(19) $V^m = \Pi^m(c_2) - \Pi^m(c_1).$

This reflects the inertia identified by Arrow (1962). The innovator's incentive to invent reflects the returns from commercializing the invention through either licensing or entrepreneurship. The innovator's incentive to invent equals

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

Compare the inventive to invent for a monopolist and for an innovator who is a potential entrepreneur. The incumbent firm using its initial technology earns more as a monopolist than with competitive entry, $\Pi^m(c_1) > \Pi_1(c_1, c_2)$. This implies that the monopolist's incentive to invent is less than the benefit of adopting the new technology,

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

For $b \leq b^*$, the benefit of adopting the new technology is less than the profit from entrepreneurial entry,

$$\Pi^m(c_2) - \Pi_1(c_1, c_2, b) \leq \Pi_2(c_1, c_2, b) = V^I,$$

The next result compares the incentive to invent a new process technology when the entrant and the incumbent each offer a differentiated product.

Proposition 4. When products are sufficiently differentiated, $0 \leq b \leq b^*(c_1, c_2)$, or when the innovation is sufficiently incremental, $c_2 > c_2^*(c_1, b)$, the innovator's incentive to invent is greater than that of an incumbent monopolist, $V^I > V^m$.

When entrepreneurship is the equilibrium outcome, it can be shown that the innovator's incentive to invent is greater than the monopolist's increased profits from adoption, $\Pi^m(c_2) - \Pi_1(c_1, c_2, b)$, regardless of the value 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

(21) $\quad \alpha' = [\Pi^m(c_2) - (\Pi^m(c_1) + \Pi_2(c_1, c_2, b))] / [\Pi^m(c_2) - (\Pi_1(c_1, c_2, b) + \Pi_2(c_1, c_2, b))].$

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]

Proposition 4 is related to Arrow's (1962) original insight that competition improves the incentive to invent. The innovator's incentive to invent is 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. The incumbent monopoly's inertia from initial technology is eliminated because the incumbent compares monopoly profits with profit after entry of the entrepreneur. 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.

The extent of the innovation also affects the innovator's choice in a market with differentiated products. Arrow (1962) defines an innovation to be drastic or nondrastic depending upon whether the monopoly price with the new technology is less than or greater than the unit costs under the old technology. In the present setting, the critical value of the substitution parameter depends on the values of the initial and new technologies. The quality of the new technology affects the outcome of competition after entrepreneurial entry. This implies that the quality of the new technology relative to the

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[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.

existing technology affects the returns to adoption by the monopolist. Thus, the quality of the new technology affects both the returns to technology transfer and the industry earnings with entrepreneurship.

4.3   The New Product Design is Transferable

The innovator prefers entrepreneurship to technology transfer if and only if the returns to entry are greater than or equal to 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 or equal to monopoly profits with the new product design and the initial production process,

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

Recall that the profits of the two-product monopolist with the initial technology equals $\Pi^m(c_1, c_1; b) = \dfrac{2}{1+b} \dfrac{(2-c_1)^2}{4}$.

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,

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

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.

<u>Proposition 5.</u> When only the new product design is transferable, the following hold. (i) 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 $b^{DD} = b^{DD}(c_1, c_2)$. (ii) Entrepreneurial entry occurs if and only if $c_2 < c_2^D(c_1, b)$, so that significant 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

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

This implies the following result.

<u>Proposition 6.</u>   Consider the incentive to invent when 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 $b^{DD} = b^{DD}(c_1, c_2)$ 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.   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 technology both to the existing firm and to an entrepreneur. The innovator 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 innovator could make such a choice, the outcome would be the same as the situation in which the innovator can become an entrepreneur, which was already considered in the previous section.

5.1   The Entrepreneur Does Not Have the Initial Technology

Consider the strategic innovation game when the potential entrepreneur has access to 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 technology. Suppose first that the entrepreneur can only enter the market by adopting the new 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 technology.

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

entrepreneur 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 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 technology, the incumbent earns $\Pi^m(c_2) - R$ and the entrepreneur's payoff is zero. If neither firm adopts the new technology, the incumbent firm earns $\Pi^m(c_1) - R$ and the entrepreneur's payoff again is zero. Table 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 $R \leq \Pi_1(c_2, c_2, b) = \Pi_2(c_2, c_2, b)$. 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

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

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 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 innovator induces adoption by both firms, which differs from the possible outcomes when the innovator 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 innovator induces adoption by only the entrepreneur, which corresponds to the equilibrium with entry when the innovator and the potential entrepreneur are not independent.

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

<u>Proposition 7.</u> When the inventor is independent and the entrepreneur does not have access to the initial technology, entrepreneurship always takes place.

When the inventor is independent from the entrepreneur, royalties that allow technology transfer to the incumbent firm always involves also selling to the entrepreneur. The entrepreneur values the innovation more than the incumbent because of the inertia from the initial technology. Choosing greater royalties excludes the incumbent firm so that the innovator 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 the incumbent firm.

The independent inventor's incentive to invent equals $V^* = \max \{2R^*, R^{**}\}$. Proposition 6 shows that an independent inventor benefits from competition for licenses between the entrepreneur and the incumbent firm in the adoption-and-entry game.

<u>Proposition 8</u>. The independent inventor's incentive to invent, V^*, is greater than or equal to that of non-independent innovator, V^I, if the non-independent innovator has limited bargaining power, $\alpha \leq \alpha^{**}$, where

$\alpha^{**}=[2(\Pi_1(c_2, c_2, b) - \Pi_1(c_1, c_2, b)) - \Pi_2(c_1, c_2, b)]/[\Pi^m(c_2) - \Pi_1(c_1, c_2, b) - \Pi_2(c_1, c_2, b)]$.

<u>Proof.</u> 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 non-independent 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 $\alpha \leq \alpha^*$. Q.E.D.

An independent inventor is at least as well off as a non-independent inventor who prefers to become an entrepreneur regardless of his bargaining power. An independent inventor

is at least as well off as a non-independent inventor who prefers technology transfer but has a low bargaining power. The non-independent 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 if products are sufficiently differentiated. Let b^* be the critical value of the product differentiation parameter such that industry profits increase with entry when only the process innovation is transferable.

Proposition 9. The independent inventor has a greater incentive to invent, V^*, than that of the monopolist, V^m, if products are sufficiently differentiated, $0 \leq b \leq b^*$.

Proof. From the definition of V^* and b^*, it follows that
$$V^* \geq \Pi_2(c_1, c_2, b) \geq \Pi^m(c_2) - \Pi_1(c_1, c_2, b) > \Pi^m(c_2) - \Pi^m(c_1) = V^m. \blacksquare$$

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.

5.2 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 technology. The entrepreneur can enter with the initial technology which is available without cost or the entrepreneur can obtain the new 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 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 technology.

Proposition 10. When the inventor is independent and the initial technology is available to both the incumbent firm and the entrepreneur, the inventor transfers the technology to both the incumbent and the entrepreneur.

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

Table 1   The technology adoption and entrepreneurship game with payoffs (Existing firm 1, Entrepreneurial firm 2).

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	$\Pi_1(c_1, c_2, b)$, $\Pi_2(c_1, c_2, b) - R$	$\Pi_1(c_1, c_1, b)$, $\Pi_2(c_1, c_1, b)$

Table 2   The technology adoption game with payoffs (Existing firm 1, Entrepreneurial firm 2) when the initial technology is available to both the incumbent firm and the entrepreneurial firm.

6.   Conclusion

Product differentiation fundamentally affects the choice between technology transfer and entrepreneurship. By mitigating competition, product differentiation creates opportunities for entrepreneurs to operate beside existing firms. With product differentiation, industry profits with entrepreneurial entry can be greater than monopoly profits for an incumbent firm. An innovator then will choose entrepreneurship rather than technology transfer. The analysis shows that when the products are not close substitutes, the innovator will choose entrepreneurship. When only the process innovation is transferable, incremental innovations will lead the innovator to choose entrepreneurship and major innovations will lead the innovator to transfer the technology to the incumbent firm. When only the product innovation is transferable, major innovations will lead the innovator to choose entrepreneurship and incremental innovations will lead the innovator to transfer the technology to the incumbent firm. In addition, if the innovator is independent from the entrepreneur, the innovator always will transfer technology to the entrepreneur. This implies that choice between cooperation and competition reflects strategic interaction between innovators and existing firms and is affected by the costs of technology transfer.

Consumer benefits from product variety lead to more entrepreneurship. When innovators develop new production processes, entrepreneurs enter the market by providing new products that use the new production processes. The interaction between product differentiation and adoption of process technology plays a crucial role. This helps explain Schumpeter's assertion that entrepreneurship involves "new combinations." Product differentiation generates rents for entrepreneurs by mitigating the intensity of product market competition. When products are differentiated sufficiently, entrepreneurial entry causes industry profits to be greater than what would be obtained by technology transfer to the incumbent monopoly.

Entrepreneurship opens new avenues for innovation beyond technology transfer. This is consistent with the many empirical observations of the close association between innovation and entrepreneurship. Together, technology transfer to incumbents and the establishment of new firms increase the returns to inventive activity. The innovator who chooses between technology transfer and entrepreneurship has a greater incentive to

invent than the incumbent monopolist. By embodying innovations in new firms, entrepreneurs profoundly influence the rate and direction of inventive activity.

The effects of product differentiation suggest potential industry dynamics. Suppose that the substitution parameter initially takes a high value close to one. Then, a series of innovators with superior technologies will choose to sell their idea to the incumbent firm, which experiences technological improvements. Then, suppose that the substitution parameter declines. At some point, innovators will stop selling their ideas to the incumbent firm and switch to entry. In contrast, with a rising substitution parameter, innovators will switch from entrepreneurial entry to selling their ideas to incumbents.

Opportunities for technology transfer and for entrepreneurship affect incentives to invent for the incumbent firm and the innovator. The analysis took innovations as given, following Arrow's (1962) approach. The model can be generalized to include endogenous R&D. Economic factors that encourage or discourage entrepreneurship will impact innovation and the choice between technology transfer and entrepreneurial entry. In addition, economic factors that affect the costs of technology transfer will affect incentive 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. By offering a significant alternative to technology transfer, entrepreneurs exert considerable influence on the rate and direction of inventive activity.

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