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Introduction

Much like the popular myth that a bumblebee's flight is aerodynamically impossible, experts often suggest that innovative entrepreneurship is economically impossible. Entrepreneurs must be irrationally optimistic because there are few economic returns to innovative entry. Entrepreneurs cannot innovate effectively because incumbent firms have better complementary assets. Entrepreneurs cannot possibly innovate because only incumbent firms have the necessary size and market power to support innovation. And yet, they fly!

Innovative entrepreneurs add value to the economy through individual initiative, creativity, and flexibility. Innovative entrepreneurs help overcome two types of institutional frictions. First, existing firms may not innovate efficiently because of incumbent inertia resulting from various organizational rigidities. The innovative entrepreneur compensates for incumbent inertia by embodying innovations in new firms.

Second, markets for inventions may not operate efficiently because of transaction costs (search, bargaining, contracting, monitoring), imperfect IP protections, costs of transferring tacit knowledge, and imperfect information about discoveries. The innovative entrepreneur addresses frictions in markets for inventions through own-use of discoveries and adoption of innovative ideas.

This chapter presents a dynamic economic framework that will be applied to study the innovative entrepreneur. The entrepreneurial process has three stages: invention, entrepreneurship, and competitive entry. The dynamic framework emphasizes the interaction between the personal consumption-saving decisions and the business decisions of the individual inventor and entrepreneur. As economic functions change, the individual's role shifts from inventor to entrepreneur to owner, although there may be different individuals at each stage. The time line of the three-stage entrepreneurial process appears in Figure 1.1.

At the *invention stage*, an independent inventor expends effort and investment in commercial, scientific, and technological R&D. The independent inventor implements discoveries either by becoming an entrepreneur or by contracting to transfer technology to potential entrepreneurs, established firms, or market intermediaries.

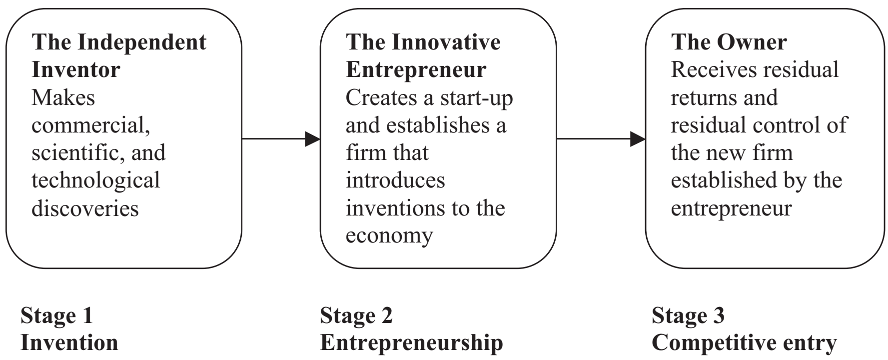

Figure 1.1. The dynamic economic theory of the innovative entrepreneur has three stages: invention, entrepreneurship, and competitive entry. The individual's role shifts from independent inventor to innovative entrepreneur to owner. The same individual or different individuals or teams of individuals can act in each stage and the process can terminate at any stage.

At the *entrepreneurship stage*, an entrepreneur creates a start-up to implement inventions and to form the basis of a new firm. The innovative entrepreneur who creates the start-up can be the initial inventor, a specialist entrepreneur, or a member of a team of entrepreneurs. The entrepreneur decides whether to be innovative or replicative. Innovative entrepreneurs differ from replicative entrepreneurs who imitate or purchase existing business models. The innovative entrepreneur combines inventions, initiative, and investment to create the start-up.

Finally, at the *competitive entry stage*, the entrepreneurial process ends successfully when the *foundational shift* occurs, that is, when the innovative entrepreneur converts the start-up to a firm that enters the marketplace. The start-up becomes a firm when it is financially separable from the entrepreneur and other owners in the sense of Irving Fisher's Separation Theorem (see Spulber, 2009a, 2009b). Sufficient investment and earnings are necessary to generate financial separation. An entrepreneur who founds the firm then becomes an owner of the firm, receiving residual returns and residual rights of control. Ownership of the firm is shared among members of the entrepreneurial team and with investors.

Understanding the decisions and characteristics of innovative entrepreneurs helps answer the major questions in the field of Innovation and Entrepreneurship:

1. The Question of Entrepreneurial Motivation: Why do individuals choose to become innovative entrepreneurs?
2. The Question of Innovative Advantage: When do entrepreneurs innovate more efficiently than do incumbent firms?
3. The Question of Competitive Pressures: How does competition affect incentives to innovate?
4. The Question of Creative Destruction: When do markets choose innovative entrepreneurship over technology transfer to incumbents?

5. The Question of the Wealth of Nations: How do innovative entrepreneurs affect international trade and economic prosperity?

1.1 The Independent Inventor and the Market for Inventions

Invention and entrepreneurship are different functions and involve different capabilities. Specialization of function and division of labor among inventors and innovative entrepreneurs can generate economic efficiencies. These efficiencies are realized through market transactions between independent inventors and innovative entrepreneurs, leading to gains from trade in the commercialization of inventions. Conversely, individuals may realize complementarities between inventive and entrepreneurial capabilities, leading some inventors to become innovative entrepreneurs. Also, inventors may become innovative entrepreneurs to avoid frictions in the market for inventions.

The Independent Inventor

Independent inventors are individuals who engage in R&D and obtain rewards from their discoveries. Independent inventors include freelancers, academics, consultants, employees, and managers of existing firms. The inventor's capabilities can include those of a researcher in the sciences, mathematics, computer science, engineering, social sciences, and business, including finance, marketing, accounting, operations, and management strategy. Independent inventors are distinct from companies that engage in R&D, including specialized research firms and laboratories, consulting companies, and firms that vertically integrate R&D and production. Firms also engage in R&D through research consortia and joint ventures.

Inventors maximize their life cycle utility of consumption. The independent inventor may anticipate financial rewards from the commercialization of inventions through licensing or sales. The independent inventor also may expect rewards from becoming an innovative entrepreneur and implementing the inventions. The independent inventor may receive grants for ongoing research and may expect future grants if current research is successful. The independent inventor also may receive compensation from future employment and consulting. The independent inventor may obtain indirect rewards, including enjoyment of research, satisfying scientific curiosity, and recognition of achievement by peers and society at large. University researchers benefit from salary increases, promotions, and a share of royalties.

Independent inventors are likely to design inventions that address particular needs of consumers and firms. For example, Andrew R. Hicks (2008) designed a curved automobile mirror with a 45-degree field of view that eliminates the driver's blind spot with minimal distortion. Improving the driver's view of traffic has the potential to reduce accidents and save lives. The inventor, a mathematics professor at Drexel University, introduced a mathematical algorithm that solved the mirror design problem.[1]

An independent inventor differs from an employee whose inventions are owned by the company that employs him. However, some independent inventors are employees of universities, research laboratories, and companies. Some employees keep their inventions secret and leave the company to become independent inventors and possibly innovative entrepreneurs (Bhide, 1994). Some companies create spin-offs that allow employees to implement their inventions (Anton and Yao, 1995). Inventors who are researchers at universities and laboratories can commercialize their inventions through their organizations, or they may be able to commercialize their inventions independently.[2]

The Market for Inventions

The market for inventions has transaction costs as in most markets: search, bargaining, pricing (royalties and transfer fees), and contingent contracting. Imperfect protections for IP rights also create frictions in markets for inventions, because inventors may need to reveal the details of their inventions to potential buyers, raising the risks of imitation or expropriation. The imperfect transferability of complex multidimensional innovations also can create market inefficiencies because of the transaction costs of coordinating the transfer of interrelated inventions. The problem of inventors' tacit knowledge generates market frictions because of the costs of codifying, communicating, and absorbing that knowledge. Asymmetric information about the features of inventions results in transaction costs associated with adverse selection and moral hazard.

Despite these frictions, the market for inventions is a major contributor to technological change.[3] The market for inventions includes many types of disembodied technology, such as patents, licenses, blueprints, chemical formulas, biological molecular structures, industrial designs, business plans, training, and consulting. The market for inventions also includes embodied technology, such as software,

1 Robert A. Hicks received United States Patent 8180606, "Wide Angle Substantially Non-Distorting Mirror," assigned to Drexel University on May 15, 2012. http://www.uspto.gov/web/patents/patog/week20/OG/html/1378-3/US08180606-20120515.html.

2 For studies of university researchers and specialized research firms, see Prevezer (1997), Galambos and Sturchio (1998), Zucker, Darby, and Armstrong (1998), Zucker, Darby, and Brewer (1998), Audretsch (2001), Jensen and Thursby (2001), and Lowe and Ziedonis (2006).

3 For empirical studies, see Machlup (1962), Cohen and Levinthal (1990), Mowery and Rosenberg (1991), Malerba and Orsenigo (2002), Ziedonis (2004), Laursen et al. (2010), and Clausen (2011). For useful surveys, see Arora et al. (2001), Malerba (2007), and Arora and Gambardella (2010). Markets for inventions are also international; Anand and Khanna (2000) study licensing agreements in chemicals, electronics, and computers; Tilton (1971) and Grindley and Teece (1997) examine licensing in the international diffusion of semiconductors and electronics; and Arora et al. (2001a, 2001b) consider international markets for technology in the chemical industry.

information and communications technology (ICT), laboratory equipment, and capital equipment. The market for inventions further includes commercial inventions in the form of franchise contracts that require up-front payments, royalties, and purchases of complementary resources. Inventions also can be embodied in start-ups and firms so that some mergers and acquisitions (M&A) involve technology transfers.[4]

The demand side of the market for inventions includes entrepreneurs and established firms who implement inventions. The supply side of the market for inventions consists of independent inventors and companies engaged in R&D. The market for inventions also includes specialized intermediaries that buy and sell inventions. The activities required to obtain an invention include: licensing or buying the invention from the inventor; subcontracting R&D to an independent inventor or to another firm; forming a partnership with an inventor to conduct research and to develop to the invention; and establishing internal R&D facilities.

Private ordering addresses the problem of transaction costs in the market for inventions. First, firms may internalize R&D by vertically integrating invention and production. Choosing whether to vertically integrate R&D and production or to purchase inventions is a form of the Coasian "make-or-buy" choice. Firms will internalize R&D when the costs of managing transactions within the firm are less than transaction costs in the market for inventions. Firms may both make and buy inventions. Furman and MacGarvie (2009), for example, find that the growth of in-house R&D capabilities in large pharmaceutical firms depends heavily on technology transfer through firm-university collaborations and contract research.

Second, intermediaries can improve efficiency of the market for inventions. These types of intermediaries perform a variety of important economic functions that increase allocative efficiency and reduce transaction costs. Intermediaries in the market for inventions engage in pricing, market making, matching buyers and sellers, reducing moral hazard, providing information to reduce adverse selection, and providing contracting services. Specialized intermediaries in markets for IP invest in legal protections for patents, pool patents to reduce costs of coordination, and provide market information to buyers and sellers. Companies such as Intellectual Ventures buy and sell patents and finance invention.

Finally, and most importantly for our discussion, inventors may bypass the market for inventions entirely through own-use of their inventions as innovative entrepreneurs. The "use-or-sell" choice is affected by the trade-off between the transaction costs of innovative entrepreneurship and transaction costs in the market for inventions. Various studies of individual academic scientists and engineers illustrate the basic choice between innovative entrepreneurship and technology transfer. Many entrepreneurial firms are spin-offs from universities.[5] Lowe and

4 Blonigen and Taylor (2000) consider acquisition of start-ups by established firms in the U.S. electronics industry.

5 See O'Shea et al. (2005) and the references therein.

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 entrepreneurial start-ups 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 more than 75 percent of inventions licensed to start-ups "were reviewed by established firms either sponsoring the research or through nondisclosure agreements with the opportunity to license" (Lowe and Ziedonis, 2006, pp. 176–177).

In practice, vertically integrated producers that undertake internal R&D also purchase technologies in the market for inventions. The commercialization of inventions depends on the relative performance of independent inventors and vertically integrated research labs within major corporations (Chandler, 1977; Audretsch, 1995a). Veugelers and Cassiman (1999) find that small firms either conduct their own R&D or purchase inventions, and large firms combine R&D activities with external purchases of inventions.[6] Pellegrino et al. (2011) show that for "young innovative companies," innovation intensity mainly depends on embodied technical change from external sources rather than in-house R&D, while in-house R&D plays a more important role for mature innovative firms.

Biotech inventors who are associated with universities establish new firms or attract firms seeking technology transfers (see Prevezer, 1997; 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)

6 See Cassiman and Veuglers (2002, 2006) on complementarity between the firm's knowledge sourcing and innovation. See also Ropera et al. (2008), Laursen et al. (2010), and Clausen et al. (2011).

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).

Academic inventors and universities choose among various commercialization options, essentially choosing between entrepreneurship and technology transfer to existing firms. Vohora et al. (2004) study nine entrepreneurial start-ups in the United Kingdom that were university spinouts (USOs). The academic entrepreneur that established the company Stem Cell attempted to transfer his technology to existing firms that had sponsored his research. He observed: “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). They 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. (p. 156)

University inventors tend to receive greater royalties from entrepreneurial entrants (Lowe and Ziedonis, 2006). Commercialization tends to occur through agreements between inventors and existing firms in industries such as biotech (Lerner and Merges, 1998). Gans and Stern (2000, p. 486) find that in biotech, “nearly all successful firms have either licensed their key innovations, joined in downstream alliances, or been acquired outright by product-market incumbents.”[7]

Inventors also can be specialized firms that develop products and processes that are inputs to other firms. These specialized firms face the problem of choosing between entrepreneurial entry downstream and 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 U.S. biotech, 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 that needed to decide how best to commercialize their discoveries. Small biotech firms and major

7 See also Orsenigo (1991) and Stern (1995).

pharmaceutical companies chose between cooperation and competition. Small biotech firms tended to engage in technology transfer to larger pharmaceutical companies rather than entering the market to produce and sell products based on their discoveries: "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 occurred in other industries. For example, in the chemical industry, specialized engineering firms (SEFs) chose entrepreneurial entry in R&D rather than transferring technologies to incumbent chemical companies. However, once they were established, these entrepreneurial entrants marketed process technology to large oil companies and chemical companies (Arora and Gambardella, 1998). In the photolithographic alignment equipment industry between 1960 and 1985, innovative entrants sold equipment to major semiconductor manufacturers (Henderson, 1993). Initially single-product start-ups entered the industry, but as incumbent firms became large and diversified, later entrants were firms with experience in related technologies (Henderson, 1993). Incumbents were displaced by later entrants who introduced innovations in photolithography rather than transferring their technology (Kato, 2007).

Increased invention by university researchers has resulted in the emergence of commercialization efforts by universities themselves. The university technology transfer office (TTO) acts as an intermediary that commercializes the inventions of university faculty. The TTO invests in expertise needed to evaluate and certify the quality of inventions. The TTO also handles the transactions involved with licensing inventions to potential adopters.[8] The university generally takes ownership of inventions produced by faculty based on employment contracts. Additionally, the Bayh-Dole Act permits universities, nonprofit organizations, and small businesses to own inventions that result from federal government funding rather than transferring ownership to the government.[9] Just prior to the Act, the government owned 28,000 patents, of which only about 5 percent were commercialized.[10] A study found that university patent licensing in the first 25 years of the Act resulted in 4,350 new products and the establishment of 6,000 new firms, with a rate approaching 700 new firms per year.[11] The costs of commercializing and developing university inventions is estimated to exceed invention costs by a factor of 10, with a new drug having

8 See Heidrun and Ozdenoren (2005), Jensen and Thursby (2001a, 2001b, 2003), and Siegel et al. (2000).

9 University and Small Business Patent Procedures Act, 1980, 35 U.S.C. § 200–212, 37 C.F.R. 401.

10 Council on Governmental Relations, The Bayh-Dole Act: A Guide to the Law and Implementing Regulations 1–2 (1999), http://www.cogr.edu/docs/Bayh_Dole.pdf, cited by McDonough (2006, p. 199).

11 See Bayh, Allen, and Bremer (2009, p. 3). They also cite a study by the Biotechnology Industry Organization (BIO) of university patent licensing between 1996 and 2007, which found that half of those reporting said their companies were based on university licenses while three-quarters of companies report that they had university licensing agreements.

development costs of $800 million to $1.3 billion and requiring 10 years for development and regulatory approval.[12] An alternative to IP ownership and intermediation by universities would allow faculty to seek intermediation by competitive independent licensing agents that play important roles in IP markets.[13]

The development of large-scale corporate laboratories may reflect economies of scale in R&D and economies of scope between innovation and manufacturing.[14] Larger existing firms' incentives to innovate are different from those of smaller firms, including entrepreneurial entrants, and larger firms pursue different types of inventive activity.[15] Acs and Audretsch (1987) find that large firms tend to have a competitive advantage in industries that are capital intensive, concentrated, highly unionized, and produce differentiated goods, whereas small firms tend to have a competitive advantage in industries that are highly innovative, rely on skilled labor, and innovate earlier in the industry life cycle. Mowery (1983) found that in the period between 1900 and 1940, there was a complementarity between in-house research and contract research projects so that contract research was not an effective substitute for in-house research, and firms without in-house facilities experienced a disadvantage in R&D and innovation.[16]

Competition among inventors offering substitute technologies can occur with the diffusion of new categories of technologies (Baptista, 1999). Karlson (1986) studies the adoption of competing inventions by U.S. steel producers. Stoneman and Toivanen (1997) consider the simultaneous diffusion of five different technologies (computer numerical controlled machines, numerically controlled machines, coated carbide tools, computers, and microprocessors) and discuss whether technologies are complements or substitutes. Huckman (2003) examines hospital adoption decisions for substitute cardiac procedures. Legal decisions involving a wide variety of inventions in different industries have considered the effects of competition among substitute inventions.[17]

1.2 The Innovative Entrepreneur and the Start-Up

An *innovative entrepreneur* is an entrepreneur who creates a start-up and establishes a firm that is the first to apply an invention. An *invention* is a commercial, scientific,

12 See Bayh, Allen, and Bremer (2009, p. 3).
13 See Schramm et al. (2009).
14 See Schumpeter (1942).
15 See Winter (1984), Acs and Audretsch (1988), and Audretsch (1995b).
16 See Mowery and Rosenberg (1991) on the commercialization of invention.
17 For example, Schlicher (2000) examines *Grain Processing Corp. v. American Maize-Products Co.*, 185 F.3d 1341, 51 U.S.P.Q.2d 1556 (Fed. Cit. 1999) and related decisions. Schlicher (2000, p. 504) observes: "For purposes of determining a reasonable royalty, the market value of any invention is the difference between the profits available from use of that invention by the patent owner or, if more efficient, by the infringer, and the profits available to persons other than the patent owner from use of the next best available substitute technology that would not infringe any patent of that patent owner."

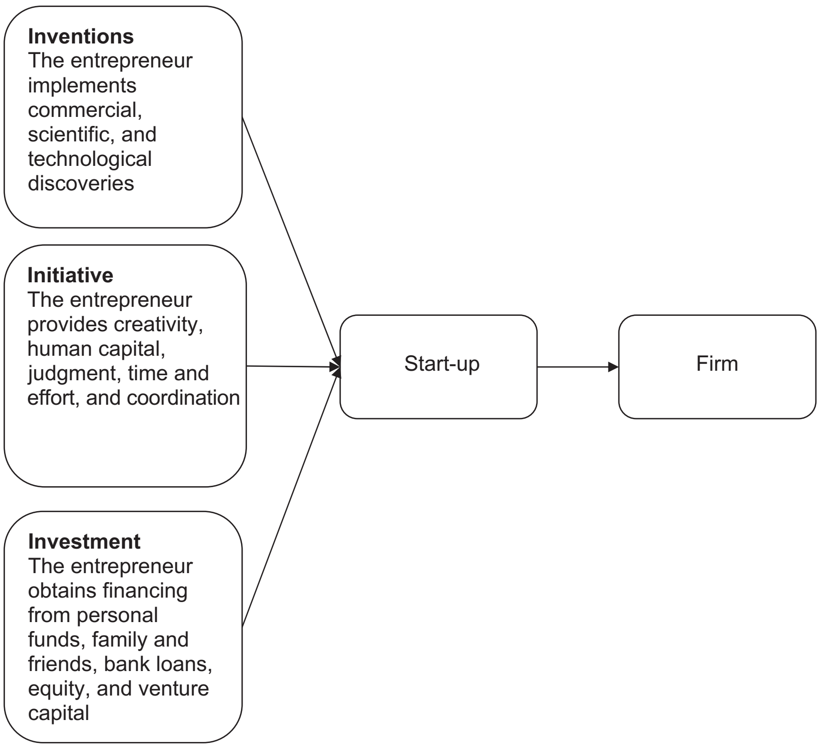

Figure 1.2. An entrepreneur creates a start-up and establishes a firm by combining inventions, initiative, and investment.

or technological discovery, but an *innovation* is something new that is introduced to the marketplace. An innovative entrepreneur can begin as an inventor who then applies commercial, scientific, and technological discoveries by becoming an entrepreneur. An innovative entrepreneur also can be a specialist who purchases or licenses discoveries from inventors and intermediaries.

The Entrepreneur

Innovative entrepreneurship is endogenous to the economy and depends on the decisions of individual inventors and entrepreneurs, among other economic actors. Entrepreneurs maximize their expected life cycle utility of consumption. Because of financial and liquidity constraints, their personal consumption and savings decisions are interconnected with their business decisions.

Innovative entrepreneurs provide a combination of inventions, initiative, and investment to the economy (see Figure 1.2). The innovative entrepreneur implements his own inventions or obtains those of independent inventors. The innovative entrepreneur applies personal initiative to create the start-up, providing creativity, human capital, judgment, time and effort, and coordination. The innovative entrepreneur's investment in the start-up is funded by personal income and wealth,