International Journal of Industrial Organization 30 (2012) 641–653

Contents lists available at SciVerse ScienceDirect

International Journal of Industrial Organization

journal homepage: www.elsevier.com/locate/ijio

Tacit knowledge with innovative entrepreneurship☆

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ARTICLE INFO

Article history:
Received 26 August 2011
Received in revised form 14 July 2012
Accepted 23 July 2012
Available online 28 July 2012

JEL classifications:
L26
O

Keywords:
Tacit knowledge
R&D
Invention
Innovation
Entrepreneur

ABSTRACT

Tacit knowledge affects the trade-off between entrepreneurship and technology transfer. I present a formal model in which an inventor and the existing firm engage in a strategic innovation game by choosing whether to compete or to cooperate through technology transfer. The model highlights how the problem of tacit knowledge affects the inventor's R&D investment and the existing firm's investment in absorptive capacity. The inventor's tacit knowledge implies that benefits from own-use through entrepreneurship can exceed the benefits from technology transfer. In equilibrium, higher-quality inventions result in entrepreneurship and lower-quality inventions result in technology transfer. R&D investment and absorption investment are strategic substitutes in the innovation game with the option of entrepreneurship. The possibility of entrepreneurship increases R&D investment and reduces absorption investment. The equilibrium probability of entrepreneurship is decreasing in the costs of R&D, increasing in the costs of absorption, and decreasing in the set-up costs of new firms.

1. Introduction

Inventors' *tacit knowledge* can make it difficult to separate discoveries from the individuals who make them. Although both inventors and adopters *know that* a discovery has particular features, some inventors *know how* to apply their discoveries better than do potential adopters. Inventors can benefit from their tacit knowledge by becoming innovative entrepreneurs who establish firms to implement their discoveries. However, entrepreneurship entails costs of setting up new firms and rent dissipation from competing with existing firms. Alternatively, inventors can transfer their discoveries to existing firms but this entails costs of codifying, transferring, and absorbing tacit knowledge and imperfect implementation of discoveries.[1] Therefore, tacit knowledge creates a fundamental trade-off between own-use of discoveries by their inventors and adoption of discoveries by others. To address this trade-off, I present a formal model that examines how inventors' tacit knowledge influences the choice between innovative entrepreneurship and technology transfer. The option of innovative entrepreneurship changes the market for discoveries and affects inventors' investment in research and development (R&D) and potential adopters' investment in absorption of discoveries.

The economic analysis of tacit knowledge presented here highlights the important role of the individual inventor. The individual inventor's tacit knowledge is essential for implementing technology. Tacit knowledge gives an *own-use advantage* to inventors who become innovative entrepreneurs in comparison with technology transfer to existing firms. This result contrasts with the standard view that complementary assets give existing firms an advantage in implementing technology.[2] Tacit knowledge creates problems for technology transfer that differ from the effects of adverse selection, moral hazard, and imperfect intellectual property (IP) protections. Tacit knowledge affects incentives for endogenous investments in knowledge production and absorption and provides incentives for innovative entrepreneurship.

The main insight is that the *marginal* returns to R&D are greater with innovative entrepreneurship than with technology transfer to an existing firm. An inventor's own-use of a discovery through innovative

☆ I gratefully acknowledge the support of a research grant from the Ewing Marion Kauffman Foundation. I thank the coeditor and referees for helpful comments that improved the analysis and presentation.

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[1] By its very nature, tacit knowledge may not be transferable to others unless it is converted to explicit knowledge. Generating explicit knowledge based on tacit knowledge entails various economic costs. An inventor seeking to transfer tacit knowledge must first attempt to codify the knowledge in explicit form, including written documents, technical descriptions, mathematics, diagrams, blueprints, computer code, and prototypes. Next, the individual seeking to transfer tacit knowledge must communicate with the receiver through messages, discussions, teaching, training, and other means. Finally, the receiver must devote time, effort, and resources to absorb the transferred knowledge, including research and development (R&D), education, training, and acquisition of equipment. Transferring tacit knowledge entails explicit costs of education, training, consulting, scholarly publications, and information services. Taken together these costs represent *absorption investment*.

[2] Teece (1986, 1988) shows that IP problems induce firms to internalize R&D and emphasizes the importance for technology transfer of the complementary assets of established firms, such as IP, human capital, marketing channels, see also Teece (2006) and Gans and Stern (2003).

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http://dx.doi.org/10.1016/j.ijindorg.2012.07.004

entrepreneurship generates greater marginal returns than adoption by the existing firm for two reasons. First, due to the inventor's tacit knowledge, the marginal returns to own-use of the invention are greater than the returns obtained by the existing firm. Second, due to creative destruction, an innovative entrepreneur who competes with an existing firm offers a lower price and sells more output than the incumbent, thus increasing the returns to the invention. Therefore, tacit knowledge and creative destruction have reinforcing effects. An inventor who anticipates becoming an innovative entrepreneur invests more in R&D than an inventor who anticipates technology transfer.

The main results of the analysis are as follows. First, I show that tacit knowledge implies that higher-quality inventions result in entrepreneurship and lower-quality inventions result in technology transfer. Second, I show that even though investments in R&D and absorptive capacity are complements in technology transfer, they can be strategic substitutes in the innovation game with the option of entrepreneurship. An inventor who anticipates greater absorptive capacity reduces R&D effort and an existing firm that anticipates more R&D investment reduces absorption investment. Third, I show that introducing the option of innovative entrepreneurship increases R&D investment and lowers absorption investment. Finally, I find that the equilibrium probability of entrepreneurship is decreasing in the costs of R&D, increasing in the costs of technology transfer, and decreasing in the set-up costs of new firms. Because the inventor and the existing firm choose between cooperation and competition, I show that the likelihood of technology transfer is correspondingly increasing in the costs of R&D, decreasing in the costs of technology transfer, and increasing in the set-up costs of new firms.

An inventor's tacit knowledge is a fundamental aspect of the process of discovery as well as subsequent diffusion of economic innovations. The development of light-emitting diodes (LEDs) illustrates the importance of the individual inventor and tacit knowledge. Shuji Nakamura invented blue, green, and white LEDs and the blue laser and developed extensive tacit knowledge about how to manufacture LEDs.[3] In a classic example, Collins (1974) examined the transfer of knowledge about the Transversely Excited Atmospheric Pressure CO_2 (TEA) Laser. Collins, (1974, p. 183) found that "the unit of knowledge cannot be abstracted from the 'carrier.' The scientist, his culture and skill are an integral part of what is known" (see also Ravetz, 1971). The inventor develops tacit knowledge through observations of complex research processes and outcomes. The inventor's tacit knowledge is also the product of personal experiences, training, insights, creativity, and capabilities rather than organizational capital, routines, or culture.[4]

The philosopher Bertrand Russell (1911, p. 120) distinguishes between knowledge by acquaintance and knowledge by description and points out that "our judgment is wholly reduced to constituents with which we are acquainted."[5] The psychology and sociology literatures further develop the concept of tacit knowledge (Cowan et al., 2000). Polanyi (1962, 1967) draws a distinction between tacit and explicit knowledge; see also Ryle (2002) on the difference between knowing-how and knowing-that. Sociologists Rogers (1962) and Coleman (1964) examine the imperfect diffusion of innovations. Citing the sociology literature, Arrow (1969) observes that "Different communication channels have different costs (or equivalently different capacities), where these costs include the ability of the sender to "code" the information and the recipient to "decode" it." Machlup's (1962) landmark study estimates that the combined costs of producing and distributing knowledge constitute nearly 30 per cent of the U.S. economy.

The closest paper to the present analysis is that of Gans and Stern (2000).[6] They observe that "under the traditional assumptions of the literature on technological competition, and in the absence of noncontractible information asymmetries between the incumbent and entrant, observations of entry by the startup into the product market represent something of an economic puzzle" (Gans and Stern, 2000, p. 487). Gans and Stern (2000) consider a three-stage model in which there is an R&D race between an incumbent and a potential entrant in the first stage. If the incumbent wins the race, the incumbent remains a monopolist, and if the entrant wins the race, the incumbent and entrant engage in bargaining in the second stage, with either technology licensing or entry occurring in the third stage. Gans and Stern (2000, p. 487) introduce a property rights or spillover parameter and allow the incumbent to continue to invest in R&D during the bargaining stage that may be used to "expropriate the entrant's rents from successful innovation." Therefore, the incumbent considers the startup's R&D a strategic substitute for the incumbent's in-house research. The present model differs from Gans and Stern (2000) in a number of ways. In my model, only the inventor engages in R&D, not the incumbent firm, which highlights the role of tacit knowledge. In my model, the incumbent firm cannot expropriate the inventor's discovery so that the inventor has property rights to the invention. Gans and Stern (2000, 2002, 2003) do not address tacit knowledge. The value added of the present work is that the inventor's tacit knowledge generates benefits from own-use of the discovery, which affects R&D investment, absorption investment, the quality of invention, the quality of technology transfer, and entrepreneurship.

The analysis of tacit knowledge is related to some problems of imperfect knowledge transmission in organizations (Dessein and Santos, 2006; Dewatripont, 2006). A question in models of organization is whether tasks should be centralized or decentralized depending on the trade-off between imperfect coordination among two agents and the advantages of division of labor. This is related to our analysis, in which the inventor and the existing firm choose whether to cooperate or to compete, depending on the trade-offs between knowledge transfer and own-use of knowledge. This allows the endogenous formation of organizations through the choice between contracts for technology transfer to the existing firm and the establishment of a new firm that competes with the existing firm.

The present model of tacit knowledge helps to explain empirical observation of inventors participating in the innovation process, joining new ventures as entrepreneurs or employees. Zucker et al. (1998b) consider the early entrants into biotechnology and the new biotech units of existing firms. They show that the location and timing of usage of the new technology 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."[7] Particular innovations are closely tied to the complementary knowledge and capabilities of individual "star scientists." Zucker et al. (2002b) find that for "breakthrough discoveries where scientific productivity becomes relevant to commercialization, the labor of the most productive scientists is the main resource around which firms are built or transformed."[8] Their empirical results on "star scientists" in biotech suggest that inventors in that industry who have

[3] Nakamura won the 2006 Millennium Technology Prize for his invention of blue, green, and white LEDs and the blue laser. See Nakamura et al. (2000) and Johnstone (2007).

[4] Spender (1996) elaborates on the distinction between individual psychological tacit knowledge and social collective tacit knowledge that is shared among individuals. Spender (1994) also distinguishes between individual and collective knowledge that is explicit and argues that different types of knowledge generate different economic rents. Many organizational studies have elaborated on the notion of tacit knowledge in groups, see Sandelands and Stablein (1987), Weick and Roberts (1993), and Nonaka and Takeuchi (1995).

[5] Russell (1911, p. 117) states that "The fundamental epistemological principle in the analysis of propositions containing descriptions is this: Every proposition which we can understand must be composed wholly of constituents with which we are acquainted" (see also Russell, 2000).

[6] See also Gans et al. (2002) and Gans and Stern (2003).

[7] Zucker et al. (1998a, 1998b, p. 290)

[8] See also Zucker and Darby (2001) for a study of Japan's star scientists in biotech, Zucker et al. (1998a) on star scientists in US biotech, and Zucker et al. (2002a) on the economic value of the "tacit knowledge" of star scientists.