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A dynamic model of open source vs proprietary R&D

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ABSTRACT

We propose a dynamic model in which firms compete to produce sequential and cumulative innovations, and in which the more firms do research in one sector the more likely it is that one of them innovates. Firms choose research effort and whether to patent innovations or to use an Open Source license like the General Public License. We show that (*i*) patents generate a larger stationary reward but foreclose research within a sector, and that (*ii*) Open Source generates a smaller stationary reward but allows everyone to use the technology, and therefore, by attracting firms to the sector, it induces a faster pace of innovation. We characterize all the equilibria of the model and show that in equilibrium an Open Source sector appears only after a proprietary sector. We also find conditions under which the model has a unique equilibrium, in which a proprietary and an Open Source sector coexist and compete in the short run, but the Open Source sector dominates the industry in the long run. We use our model to study whether patents are inefficient, and to explain firms' behavior in the software and the biomedical industry.

1. Introduction

Many firms use monopoly rights to protect their innovations, but many do not and instead allow competitors to use, copy, and modify their innovations for free. For example, firms that produce software often do not encrypt the source code. They leave it open and release it through Open Source licenses that allow the licensee to redistribute both the code and every derived work.[1] Firms use similar practices also in other industries, including agriculture, automotive, and biomedicals. In these industries firms that use monopoly rights and firms that renounce these rights coexist and compete.

While a large literature has studied how intellectual property rights affect innovation, only some papers study why firms choose a specific type of rights, and only a very few papers allow firms that choose different types of rights to compete. We do so in this paper. We show that firms may find profitable to grant a licensee the right to copy their innovation, but that this happens only if another firm has already chosen to deny this right.

We develop a dynamic stochastic game of R&D competition. The game describes an industry with a fixed number of firms and two sectors, in each of which firms produce a version of a differentiated good. We consider industries with some specific characteristics. (i) Innovation is cumulative. A firm that wants to develop a new idea into an innovation has to handle the existing technology and hence has to obtain a license from the right holder. (ii) Firms cannot write contracts contingent on either their investment in research or on the resulting innovation. Once the cost of research is sunk, they can bargain over a license, and in this case it is the right holder that has all the bargaining power. (iii) Research efforts are

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[1] For a definition of Open Source software see (Initiative, 2005).

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complementary. When more firms do research in the same sector the probability that one of them obtains an idea increases. (iv) It takes time to imitate another firm's innovation. During this time the firm that has innovated is the only one that can market the innovation.

We distinguish between innovative and competitive firms. In each period the innovative firms do research, choose a regime of licenses, and bargain for a license, and then both the innovative and the competitive firms compete in the market. Which regime of licenses firms choose, that is which rights they choose to trade, determines the profit they make in the market, the advancement of the sector, and hence the individual returns both to research and to the rights themselves.

In our model first innovators choose between a proprietary and a non proprietary regime of licenses. Proprietary licenses work like many commercial licenses. They grant the right to use the innovation, but not the right to make copies. Non proprietary licenses work like the General Public License (GPL) underlying many Open Source projects. They grant the right to make and distribute copies both of the innovation and of derivative works, but they require that the licensee release every copy under the same terms. We will refer to the proprietary regime as the patent system and to the non proprietary regime as Open Source, but our story works equally well with copyrights[2] and it applies to industries that possibly are different from software.

We construct a profile of Markov strategies that induces the following path of play. In the initial period the innovative firms compete for a patent in the same sector. Then this sector enters the proprietary regime and makes a technological step ahead. In the next period the patent holder does research in the proprietary sector, while the non patent holders start an Open Source project in the other sector. The firms repeat these actions until the Open Source sector resets the gap. From that period on all the innovative firms, including the patent holder, do research in the Open Source sector. In the long run this sector dominates the industry, and in each period the consumers buy a new quality of the Open Source good.

We show that for some parameters these strategies form a Markov Perfect Equilibrium. When two firms bargain over a proprietary license, the patent holder makes an offer that leaves the other firm with its ex post litigation payoff. This prospect persuades a firm to avoid lines of research in which it holds no patent, with the result that only patent holders do research in proprietary sectors. This fact explains why in our model proprietary sectors cannot exploit complementarities and hence advance slowly, but alone it does not explain why the firms adopt the non proprietary regime. Indeed, faced with a patent holder, a firm could still try to establish the proprietary regime in the sector that is currently free of licenses.

If the firm becomes itself a patent holder, and as such it forecloses the sector, it begins a phase of duopoly competition with the other patent holder. This phase is lengthy, because each firm by itself innovates little, and it is risky, because who looses will leave the industry. Instead, if the firm joins the others in starting an Open Source project the sector will advance rapidly and eventually it will dominate the industry. The stationary reward the firm obtains as a winning patent holder is larger than the reward it obtains as a contributor to the Open Source project, but the associated discounted probability is smaller. If the discount factor is small and vertical differentiation is important the firm prefers the Open Source project to a patent. When firms have small discount factor they want to avoid long transitions during which they share the market and make small profits. Also, when vertical differentiation is important the profit a firm makes when it supplies the entire market is large, and so is the opportunity cost it faces when it shares the market.

Nonetheless, a firm has no incentive to start an Open Source project in the first period, when the industry is still free of licenses and the other firms are seeking a patent. At this point the firm prefers to seek a patent itself, because it knows that it can join the project at any time in the future, and exploit the patent in the meantime. We show that the requirement that in the first period the firms compete for a patent is common to all equilibria in which, for every realization of the path of play that has positive probability, eventually an Open Source project dominates the industry.

The game can have other equilibria, in each of which there is a positive probability that a single patent holder monopolizes the industry. We provide conditions under which our equilibrium and other equilibria are incompatible, so that our strategies are the only equilibrium of the game.

To study how firms choose license regimes we assume that when the game begins the industry is free of licenses and the technological gap between sectors is zero. In applications to specific industries we can choose other initial conditions. Then our strategies can induce a different path of play, which otherwise would be off equilibrium, and along which the proprietary regime wins. Broadly, our equilibrium predicts that the sector with the larger initial technological advantage is the more likely to dominate the industry. Our theory matches the recent evolution of the software and the biomedical industry.

We also compare welfare when firms can and cannot patent their innovations. In discussing the effect of patents on welfare we recognize a trade off between speed of innovation and duplication of research costs. With patents too few firms do research and the industry innovates little, while without patents the industry innovates more but too many firms do research. If the cost firms pay to do research is small compared to the benefit consumers receive from a new product, patents are inefficient.

[2] We mean that both in the case of patents and copyrights the right holder often discloses the technology only through individual license contracts that contain a non-disclosure agreement by which the licensee commits not to redistribute the technology (See (Cohen and Lemley, 2001; Maurer and Scotchmer, 2006), and the references in these papers).