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Industry equilibrium with open-source and proprietary firms

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ABSTRACT

We present a model of industry equilibrium to study the coexistence of open-source and proprietary firms. Two novel aspects of the model are (i) participation in open source arises as the optimal decision of profit-maximizing firms, and (ii) open-source and proprietary firms may (or may not) coexist in equilibrium. Firms decide their type and investment in R&D, and sell packages composed of a primary good and a complementary private good. Open-source firms share their technological advances on the primary good, whereas proprietary firms keep their innovations private. The main contribution of the paper is to determine conditions under which open-source and proprietary firms coexist in equilibrium. Interestingly, this equilibrium is characterized by an asymmetric market structure, with few large proprietary firms and many small open-source firms. We also study the limiting economy and present conditions under which large numbers favor cooperation in R&D.

1. Introduction

Collaboration in research enhances the chances of discovery and creation, not only for scientific discoveries, but also for commercial innovations. However, innovators face incentives to limit competitors' access to their innovations. According to the traditional view in the economics of innovation, innovators innovate because doing so allows them to obtain a monopolistic advantage over their competitors. Therefore, innovators should prevent others from gaining access to their discoveries, either by keeping them secret or by protecting them with patents.

This view contrasts with the free/open-source development model, in which innovators voluntarily choose to disclose their technological improvements so that other innovators can copy, use, and improve them free of charge. But if everybody has access to the same technologies, how do developers benefit from collaboration? What do they receive in exchange for renouncing their monopolistic advantages?

The answer is that open-source developers may benefit from participating in open-source projects by selling goods and services that are complementary to the open-source good. For example, IBM announced in 2001 that it was going to invest over 1 billion dollars in Linux, and today provides support for over 500 software products running on Linux, and has more than 15,000 Linux-related customers worldwide.[1]

Still, questions remain regarding what determines the choice of development model for profit-maximizing firms, why open-source and proprietary firms coexist in the same markets, and the implications of coexistence on market structure and investment incentives. Existing literature has yet to address these questions, which are the main focus of this paper.

We present a model of industry equilibrium with endogenous technology sharing. Firms sell packages composed of a primary good, such as software, and a complementary good, such as a smartphone, tablet PC, or support and training services. Firms choose their development model (open-source or proprietary), how much to invest in product development, and the price of their products. Open-source firms share their improvements to the main product, whereas proprietary firms, develop their products independently of other firms. Consumers value the quality of both goods (vertical differentiation) but also have idiosyncratic tastes for the products of different firms (horizontal differentiation).

We find that the equilibrium may have both types of firms or only open-source firms. In the equilibrium with coexistence, the market structure is asymmetric, with few large proprietary firms and many

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[1] See http://www.ibm.com/linux/ (accessed May 15, 2012).

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small open-source firms. This finding is consistent with the observations of recent surveys. Seppä (2006) compares both types of firms and finds that open-source firms tend to be smaller than proprietary firms. Bonaccorsi and Rossi(2004) show that the most important motive for firms to participate in open-source projects is that participation allows small firms to innovate.

The equilibrium depends on the resolution of a trade-off between free-riding and collaboration, which is governed by a parameter measuring the degree of public good of the investment in R&D (i.e., the effect of total vs. individual contributions on quality). When open-source firms invest in R&D, they increase quality for all firms in the project. As a consequence, open-source firms are able to appropriate a smaller fraction of their investment, in comparison with proprietary firms. Nevertheless, open-source firms share their advances on the primary good, which means that even though each firm may individually invest less than a proprietary firm, the total investment of all firms in the project may be larger than the investment of a proprietary firm.

When the degree of public good of the investment in R&D is high, free-riding is important, which leads to lower individual investments for open-source firms. As a consequence, proprietary firms have an advantage over open-source firms in terms of market share and price. On the other hand, open-source firms benefit from lower development costs. Therefore, both types of firms coexist in equilibrium: some firms choose to be proprietary, have a high investment in R&D, and benefit from high market shares and prices, and other firms choose to be open source and benefit from lower development costs.

For intermediate degrees of public good of the investment in R&D, free-riding becomes less important, and the difference in investment between open-source and proprietary firms becomes smaller. If the market-share advantage of proprietary firms is not large enough to compensate for the higher development costs, all firms choose the open-source development model. Nevertheless, a proprietary firm would invest more and produce a higher-quality product than open-source firms, so open-source prevents the entry of a higher-quality product.

Finally, when the degree of public good of the investment in R&D is low, the positive effects of collaboration are stronger than the negative effects of free-riding, and open-source firms have higher (total) investment than proprietary firms (individual investments are similar, but open-source firms share their investments). In this case, all firms choose the open-source development model to benefit from higher market shares and lower development costs than proprietary firms.

In the market equilibrium, welfare is suboptimal because of the public-good problem in open source and the duplication of effort of proprietary firms. In Section 5, we show that a subsidy to open-source development can improve welfare not only because it increases the investment in R&D, but also because it encourages commercial firms to participate in open source, thereby enhancing collaboration.

The baseline model assumes symmetric consumer preferences for open-source and proprietary products. However, given that open-source packages are based on the same primary good, open-source products are likely to be more similar than the products of proprietary firms. In Section 6, we modify the baseline model to allow for a higher cross-price elasticity between open-source products. We find that the main result of the paper still holds: when open-source and proprietary firms coexist, the market share of proprietary firms is higher than that of open-source firms. However, in this case, we also find that if the substitution between open-source products is large enough, equilibria exist in which all firms choose the proprietary development model.

We also study investment incentives and market structure under free entry. When entry costs are small, the number of firms is large and the market becomes monopolistically competitive. The equilibrium of the limiting economy depends on the limit of the ratio of open-source and proprietary firms' investments in R&D. Even though free-riding becomes more important as the number of firms increases, collaboration becomes more important, too, so either type of firm may have an advantage.

In the basic model, we find that when the degree of public good of the investment is at its maximum level (all investment is shared), the effects of free-riding and collaboration are perfectly balanced, and the equilibrium of the limiting economy has both types of firms. In this case, as the degree of horizontal differentiation decreases, the aggregate market share of open-source firms decreases, but the proportion of open-source firms in the total of firms increases. Thus, the equilibrium has fewer but bigger proprietary firms. On the other hand, when the degree of public good of the investment is less than maximal, collaboration dominates free-riding and all firms become open source. Thus we find conditions under which *large numbers favor cooperation*; that is, open source does not disappear as the number of firms grows.

Finally, in the model with lower differentiation for open-source firms, we find that if the difference in the degree of substitution between open-source and proprietary firms is large enough (so that it compensates for the positive effects of collaboration), the limiting economy has equilibria with only proprietary firms.

The model and the results are important for a variety of reasons. First, we endogenize the decision of for-profit firms to participate in open-source projects, and the equilibrium industry structure under coexistence. Second, we show that market forces and incentives may lead to an asymmetric market structure, even though all firms are ex-ante symmetric. Third, we obtain conditions under which open source can overcome free-riding and produce a good of high quality, even without coordination of individual efforts. Finally, the model allows an analysis of welfare and optimal policy.

Even though our model is specially designed to analyze open source, it has wider applicability. In particular, it can be used to analyze industries in which firms cooperating in R&D coexist with firms developing technologies on their own. In Section 1.1, we discuss how this paper relates with the literature of cooperation in R&D.

The main contribution of this paper is a tractable model of competition between profit-maximizing open-source and proprietary firms. As such, the model captures the main ingredient shaping the decision to share technologies with rivals or not: the trade-off between free-riding (appropriability) and collaboration (duplication of effort). We believe that our paper is an important first step in the analysis of the behavior of profit-maximizing open-source firms.

In Section 1.1, we present a detailed analysis of the literature. In Section 2, we introduce the basic model, which we solve in Section 3. In Section 4, we study the effects of free entry, and the equilibrium of the limiting economy. In Section 5, we present an analysis of social welfare and optimal government policy. In Section 6, we study a model with lower differentiation between open-source products. Finally, in Section 7, we discuss the main implications of our analysis and present directions for further research.

1.1. Related literature

The first papers on open source were concerned with explaining why individual developers contribute to open-source projects, apparently for free (see Lerner and Tirole, 2005; von Krogh and von Hippel, 2006, for excellent surveys). The initial answers were altruism, personal gratification, peer recognition, and career concerns.

Lerner and Tirole (2001, 2002, 2005) identify directions for further research. Some of the questions related to the present paper are as follows: (i) What are the incentives of for-profit firms to participate in open source?(ii) What development model provides higher quality and welfare? (iii) How does the competitive environment influence open source? More importantly, these authors remark that direct competition between proprietary and open-source firms has received little attention. For more recent surveys, see Maurer and Scotchmer (2006) and Fershtman and Gandal (2011).