Free Riding and Duplication in R&D
(Extended Abstract)

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Abstract

We study a model of R&D race in the exponential-bandit learning framework (Choi 1991; Keller, Rady, and Cripps 2005), in which two research firms, each endowed with an independent R&D process, choose when to exit the R&D race irreversibly. Each R&D process can be either good or bad. In the absence of research breakthrough (innovation), a firm becomes more pessimistic about its R&D process over time. We shows that strict patent may lead to excessive duplication of research efforts, while the lack of patent protection leads to free riding and under-experimentation of research opportunities. The choice of optimal patent system involves a trade-off between duplication in the early stage of R&D when both firms are optimistic and under-experimentation in the later stage when one firm has already exited and the remaining firm is pessimistic.

1 Introduction

Recent advances in the theoretical studies of strategic experimentation (e.g. Keller, Rady, and Cripps 2005) have renewed interests among economists in studying experimentation in R&D race. Various authors have applied learning model to R&D race and obtained fresh insights into this classic problem. Acemoglu, Bimpikis, and Ozdaglar (2011) study a model of experimentation in which firms can copy others' innovation. In the absence of patent protection, free riding occurs in the form of delayed experimentation. They further show that an appropriately designed patent system could implement the optimal allocation by encouraging experimentation while maintaining efficient transfer of knowledge ex post. Their analysis suggests that patent could be an efficient mean of reducing free riding. On the other hand, some authors (e.g. Chatterjee and Evans 2004) argue that winner-take-all R&D race leads to excessive duplication of research efforts. Since only one success counts, resources put into research by competitors are wasted.

In this paper, we analyze an exit game that allows us to study both free riding and duplication. In particular, we are interested in how a patent system may create or resolve these inefficiencies.

2 The Model

Time is continuous and the horizon is infinite. Two research firms, 1 & 2, each endowed with an R&D process (project), decide whether to exit the R&D race (abandon the project) at each point in time. Each firm incurs a flow cost c if she chooses to stay in the race. Once a firm quits, prohibitive sunk costs make re-entry infeasible. This assumption captures the commitment of intellectual and financial resources needed for R&D activities. Each firm's project may be either good or bad. With probability p_i, firm i's project is good. Given that firm i's project is good, breakthrough (innovation) arrives to firm i at a random time $\tau_i \geq 0$ as long as firm i stays in the race, where τ_i follows the exponential distribution with parameter $\lambda > 0$. On the other hand, breakthrough never occurs if the project is bad. While the arrival of a successful innovation is publicly observable, firms do not observe the actions of the opponent.

Costs and profits are discounted at rate r. Once a firm has achieved a breakthrough, the game ends. The innovating firm receives $\Pi + \eta$ while the non-innovating firm receives $\Pi - \eta$, where $\eta \in [0, \Pi]$. A consumer, who otherwise does not participate in the game, receives $C \geq 0$. Alternatively, the game ends when both firms exit.

The post-innovation payoffs can be interpreted as follows. Upon the arrival of a breakthrough, a patent is granted to the firm that undertakes a successful innovation. By making a payment (compulsory license fee) η to the holder of the patent, the non-innovating firm copies the innovation. The two firms then earn the duopoly profit Π in the product market. The consumer earns surplus C under duopolistic market. Thus, the total surplus in the product market in our model is always $2\Pi + C$, independent of the patent system. This assumption allows us to abstract away from the traditional analysis of patent (i.e. the trade-off between ex ante innovation and ex post allocative inefficiency) and concentrate on the trade-off between duplication and under-experimentation.

3 Main Results

A strategy of firm i in this game is an exit time $t \in [0, \infty]$ such that given no breakthrough has arrived by time t, firm i will exit. The solution concept we used is Nash equilibrium. We focus on the total welfare maximizing pure strategy equilibrium. To provide a benchmark of comparison, we define and solve the planner's problem.

Definition 1 (The planner's problem) *A pair of exit times (t_1^*, t_2^*) for the two firms solves the planner's problem if and only if it maximizes the sum of the expected discounted payoffs of the two firms and the consumer surplus.*

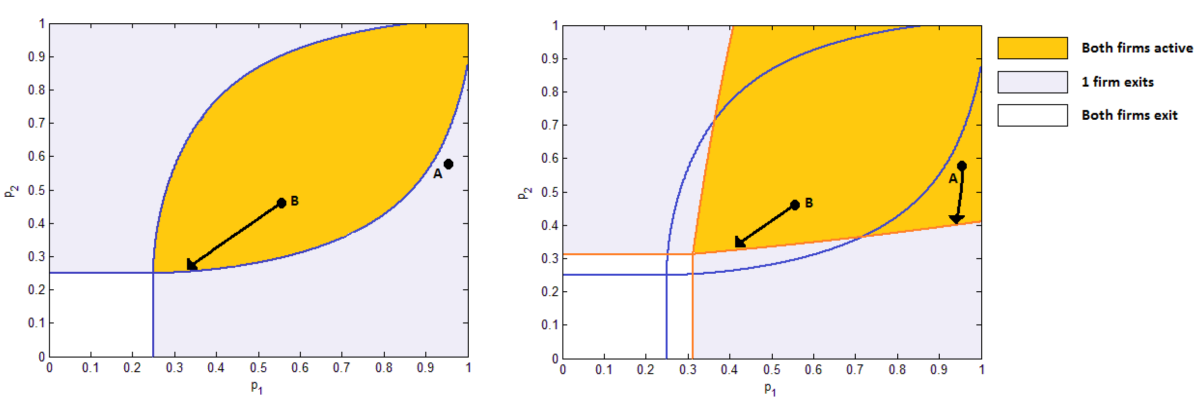

Figure 1(a) The planner's solution

Figure 1(b) Non-cooperative solution

Figure 1(a) and 1(b) illustrate the exit decisions of the planner and the individual firms given that none of the firms has exited so far, respectively.[1] In the yellow region, both firms stay in the race. In the blue region, the firm with lower belief exits immediately. In the white region, both firms exit immediately.

Suppose that the initial beliefs of the firms are given by point A, then there is excessive duplication, since the planner chooses to retire the more pessimistic firm (firm 2) immediately, yet firm 2 remains active in the non-cooperative equilibrium. On the other hand, if the initial beliefs of the firms are given by point B, the posterior beliefs of the firms decrease over time along the direction of the arrow. Upon reaching the boundary, firm 2 exits. In this case, free riding leads to premature exit of firm 2 relative to the planner's solution. One of the main results of this paper is that this is impossible under the optimal patent unless the optimal patent is already strict (i.e. $\eta^* = \Pi$).

Definition 2 (Optimal Patent) *A patent system η^* is optimal with respect to a pair of initial beliefs (p_1, p_2), if it maximizes the sum of the expected discounted payoffs of the two firms and the consumer surplus in equilibrium.*

Proposition 1 *Unless the optimal patent η^* is equal to Π, the firm with lower belief never exits too early with respect to the planner's solution under η^*. On the other hand, regardless of the patent system, the firm with higher belief never exits too late.*

We also show that it is possible to construct examples in which an increase in the beliefs (project qualities) causes the firm with lower belief to exit prematurely and lower total welfare. Such construction is impossible when the patent is strict.

4 Conclusion

In this paper, we study how patent systems may affect the amount of experimentation in an R&D race. We found that the optimal patent is sensitive to the project qualities. In general, the choice of optimal patent system involves a trade-off between duplication in the early stage and under-experimentation in the latter stage. We also show that when patent protection is weak, an increase in the qualities of the research projects may have the averse effect of aggravating free riding and decrease total welfare as a result.

References

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[1] Parameters: $\Pi = 2$, $\lambda = 1$, $c = 1$, $r = 0.05$, $C = 0$, $\eta = 1.2$.