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Irreversible investment with uncertainty and strategic behavior

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Abstract

The paper provides a model of technology adoption in the case where adopting alone is more expensive than adopting when others have already done so (network effect). In addition, if each agent gains at the expense of his rivals, he may also have an incentive for ‘preemptive adoption’. We deal with these two issues in a dynamic programing framework, where adoption is seen as a strategic switching time decision problem for agents facing an ongoing stochastic operating benefit plus sunken investment costs. The model defines the option value of investing for a continuous time stochastic game. In the case of network benefits alone, agents follow a stationary *bandwagon strategy*, representing the effect caused by a war of attrition. Yet, as network benefits reduce adoption costs after an agent has switched, rivals may follow suit. In the opposite case, where going first gives the innovator a higher payoff the *bandwagon rule* is turned over and the option value of investing first may be lower than that of going second. This gives rise to sequential adoption. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Economics defines investment as the act of incurring an immediate cost in the expectation of future payoff. However, when the immediate cost is sunk (at least

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partially) and there is uncertainty over future rewards the timing of the investment decision becomes crucial.

This paper describes the decision problem faced by agents who are already endowed with a technology and have to decide when to switch to a new one. While investing in the new technology increases the user's flow of benefits, it is more expensive to go first than to adopt the technology coordinately or later on when others have already done so. The gist of our argument is that there are 'network benefits', so the higher the number of users, the greater the advantage in terms of reduced investment costs.[1] Although agents may wish to coordinate adoption, potentially conflicting preferences over appropriation of the positive 'network benefits' make them face a choice between individual adoption and agreement, that is between cooperative and non-cooperative adoption. The decision problem resembles one of 'war of attrition' where each agent waits for his rivals to conced. The first-mover disadvantage and the strategic nature of the timing decision leads to delayed adoption. However, if each individual agent gains at the expense of his rivals, agents may also have an incentive for 'preemptive adoption'. That is, waiting might be sensible if agents fear that their opponents are likely to adopt. In this case, we would expect a non-cooperative equilibrium with early adoptions.

We deal with these two issues in a unified continuous time framework, where adoption is seen as an irreversible switching-time decision problem for agents facing an ongoing stochastic operating benefit plus sunken adoption costs. We suppose that these costs are private information, so that neither agent knows who has the greatest cost advantage. Yet, since an agent's timing decision has implications for the other agents' decisions, the optimal switching rule must take account of strategic behavior.

Regarding adoption costs, we distinguish between investment costs and set up costs. The advantage of technological change only partly depends on the reduction in the (more or less sunken) costs of the machinery which in turn may depend on the number of users. What is important are the costs associated with installation of the new technology, such as organization and training, as well as the benefits that may be forgone if better opportunities are discovered in the future. These items particularly influence users' current behavior, i.e. their choice of technology, and in turn affect the general level of diffusion of the new technology. Moreover, such costs are likely to consist of private information.

The rest of the paper is organized as follows: Section 2 places the paper in the context of the literature on irreversible investment and market structure. In Section 3 we discuss, in a two-agents framework, the link between an agent's decision for adopting an irreversible technology and the benefits of going second after a network has been set up. In Section 4 we examine the features of the (symmetric) perfect Bayesian Nash equilibrium of the 'war of attrition' option game. In Section 5 we extend the war of attrition model by introducing a preemptive effect. Final remarks are in Section 6.

[1] To make things easy, we may consider that if the cost falls as the network gets larger, this is due to positive technological externalities between producers.

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