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Information revelation through bunching

Tao Wang [a,b,*]

[a] *School of Economics, Zhejiang University, Hangzhou, Zhejiang, 310027, China*
[b] *Economics Department, Queen's University, Kingston, Ontario K7L 3N6, Canada*

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ABSTRACT

In this paper, we analyze a dynamic game of pure information externality. Each player receives a private signal and chooses whether and when to invest. Bunching occurs when a subgroup of the players make decisions contingent on their signals, while the rest of the players wait regardless of their signals. We focus on asymmetric pure strategy equilibria, where players' private information is revealed gradually through bunching. When players become patient enough, the most efficient equilibrium contains no herding of investing, while the least efficient equilibrium resembles the outcomes in an exogenous timing model. When players' discount factors differ, less patient players will bunch earlier than more patient players.

1. Introduction

Frequently in life, firms or individuals need to make Yes or No decisions under uncertainty. For example, one needs to decide on whether or not to purchase a newly-released cell phone, whether or not to go to the cinema to watch a new movie, or whether or not to make an investment. These decisions involve risk, since the outcomes are uncertain.

In this kind of environment, an agent could benefit from the observations of other agents' actions, as those actions could reveal information which is useful to the agent. The existing literature has focused on herd behavior; when later investors observe many investments (or no-investments) made by earlier investors, they ignore their own private information and follow suit. An important setup in a typical herding model is that players make their choices according to an exogenous order; they must act in their exogenously determined time slot, no sooner and no later. Therefore, the amount of information revealed through players' actions in each period is exogenously determined. We categorize this type of models as the exogenous timing models.[1]

In this paper, we analyze an endogenous timing model. In the model, players choose whether and when to invest. Every player possesses private information (good signal or bad signal) which could be revealed to other players through his action. A player must balance the benefit to wait for more information to be revealed with the discounting of payoffs due to the wait.

We focus on the pure strategy equilibria in our model. Under general conditions, these equilibria are asymmetric. In the first period and maybe some periods that follow, only a subgroup of players make decisions contingent on their private

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* Correspondence to: School of Economics, Zhejiang University, Hangzhou, Zhejiang, 310027, China.
E-mail address: wangt@econ.queensu.ca.

[1] See Banerjee (1992) and Bikhchandani et al. (1992) for the pioneer work on the exogenous timing models.

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signals; that is, to invest if the signal is good and to wait if the signal is bad. The rest of the players just wait and observe the actions of these players. We term this subgroup of players a "bunch". Being in a bunch does not require a joining action. In an arbitrary period, a bunch is just a collection of players whose strategy in that period is to invest if the signal is good and to wait if the signal is bad. Therefore, in an equilibrium, a bunch member's private information is completely revealed in that period. In contrast, in the same period, a non-member's private information is not revealed; his strategy is to wait regardless of his private signal. Therefore, information revelation in the game is done only through the actions of the bunch members, and the number of signals revealed in a period is exactly equal to the bunch size. A player waiting in one period reveals a bad signal if and only if he belongs to the bunch in that period.

We obtain many properties in our analysis. First, the bunch sizes and the amount of information to be revealed in each period is endogenously determined, instead of assumed exogenously.

Second, when players are enough patient, the least efficient asymmetric equilibrium in our model produces outcomes resembling those in the one-per-period exogenous timing model. In the equilibrium, only one player makes a decision in each period (i.e., the bunch size is one in every period) until herding occurs. This one-per-period decision making is an equilibrium behavior in our model, while it is assumed in an exogenous timing model. Meanwhile, in the most efficient equilibrium in our model, bunching occurs most often and herding occurs least often. In this equilibrium, as long as herding on waiting does not occur, players make their investment decisions one by one according to their private signal, and herding on investing completely disappears. The information revelation is maximized in this way, and the equilibrium outcome is more efficient than the one obtained from the one-per-period exogenous timing model.

Third, when players are enough impatient, the bunch sizes in our equilibria become very large. The aggregate information revealed through this very large amount of signals becomes very precise. In this case, the equilibria in our model are more efficient than any exogenous timing model.

Finally, when players differ in their discount factors, impatient players will be in earlier bunches, while patient players will be in later bunches. This resolves the multiplicity issue of asymmetric equilibria in the symmetric model where players are ex ante identical.

The literature on herding in economics was started by Banerjee (1992) and Bikhchandani et al. (1992), with the latter referring to herd behavior as information cascade, as people no longer reveal their own private information. In a herding equilibrium, the equilibrium outcome depends crucially on the private information of the first few individuals, and only these first few players' private signals are revealed in the equilibrium, leading to socially inefficient outcomes.[2] Note that these are exogenous timing models.

Chamley and Gale (1994) are the first to employ an endogenous timing model to investigate the timing of investment issue. They examine a model where an unknown number of investment options are held by a certain number of players, and the expected payoff of each individual depends on the total number of options. They focus on the symmetric mixed strategy equilibrium of that model. As players use mixed strategies, the amount of information to be revealed becomes uncertain.[3] The linkage to the exogenous timing models is not established as the latter are asymmetric in nature.

Later on, several other researchers have also used different endogenous timing models to investigate various herding and related issues. Chari and Kehoe (2004) use endogenous timing to regenerate herding in a continuous investment model. In Rosenberg et al. (2007), players play a one-armed bandit and continuously receive private signals. Zhang (2009) generalizes Chamley and Gale (1994) to both continuous signals and multiple discrete signals.[4] Chamley (2004a) addresses the non-existence of symmetric pure strategy equilibrium in Chamley and Gale (1994) by allowing players to have different beliefs drawn from a continuous distribution, and establishes the existence of multiple symmetric pure strategy equilibria. He examines the issue of large economies and finds that the amount of information revealed converges to the model in Chamley and Gale (1994) if the belief distribution is bounded. Levin and Peck (2008) also establish the existence of symmetric pure strategy equilibrium by adding a second signal (cost of investment) to Chamley and Gale's model. Zhang (1997) presents another endogenous timing model where players with different precision of signals choose their optimal timing to act in continuous time. His paper shows that the player with the highest precision invests first and then there is an investment surge leading to an information cascade. Similar results are also found in Aoyagi (1998) in a model with a different setup. All of these papers focus on symmetric equilibria. Both Gul and Lundholm (1995) and Chamley (2004b, p. 122) briefly analyze the asymmetric equilibria in the two-player case with different settings. The phenomenon of bunching requires more

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[2] Herding and information cascades have been investigated by many researchers. See Bowden (2013) for a recent survey and Chamley (2004b) for a well-organized and detailed analysis of herding and its applications in economics. Cao et al. (2011) show that even if players can communicate with each other regarding their payoffs from past choices, herding can still occur, but cannot last forever. Khanna and Mathews (2011) study a model in which players' actions may affect each other's payoffs. They find that a leader may spend more to get more precise information to avoid the adverse effect of actions being copied, and this information gain can dominate the information loss from herding.

[3] Chamley (2004a) generalizes Chamley and Gale (1994) by allowing players to have different beliefs (which is equivalent to different signals) from a continuous distribution. It is an endogenous timing model similarly to ours, and it focuses on symmetric pure strategy equilibria. We have a discrete signal distribution and we focus on asymmetric pure strategy equilibria. The comparison of information revelation between the two models is not straightforward as the signal distributions are different.

[4] Herd behavior in models of endogenous timing has been confirmed in experiments. (See Sgroi, 2003, for a review.) In an empirical study, Moretti (2011) examines the behavior of movie goers and finds that peer effect (in the form of information externality) plays an important role in their movie watching decisions.