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Clock games: Theory and experiments ☆

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ABSTRACT

In many situations, timing is crucial—individuals face a trade-off between gains from waiting versus the risk of being preempted. To examine this, we offer a model of clock games, which we then test experimentally. Each player's clock starts upon receiving a signal about a payoff-relevant state variable. Since the timing of the signals is random, clocks are de-synchronized. A player must decide how long, if at all, to delay his move after receiving the signal. We show that (i) delay decreases as clocks become more synchronized, and (ii) when moves are observable, players "herd" immediately after any player makes a move. Our experimental results are broadly consistent with these two key predictions of the theory.

1. Introduction

It is often said that to succeed in business and in life, timing is crucial. Certainly this is true in terms of new product launches, stock picking, and real estate development. It is also true in choosing a mate or even starting a revolution. These situations all exhibit a trade-off between gains from waiting versus the risk of being preempted. In this paper, we offer a theoretical model of "clock games" that tries to capture this trade-off. We then test the key implications of the model in the lab.

In a clock game, each player's clock starts at a random point in time: the time at which he receives a signal of a payoff-relevant state variable (e.g., an opportune time for a product launch). Owing to this randomness, players' clocks are de-synchronized. Thus, a player's strategy crucially hinges on predicting the timing of the other players' moves—i.e., predicting other players' clock time. The exact prediction depends crucially on the observability of moves, the speed of information diffusion, and the number and size of players. There are n players making moves in our model; thus, our setting is the finite agent analog to the "competitive" model of Abreu and Brunnermeier (2003), where there is a continuum of small players.

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While clock games are potentially quite complex to analyze, we transform the problem to one that can be readily analyzed using auction theory. In particular, the equilibrium waiting time in a clock game is isomorphic to the equilibrium bid in a multi-unit reverse first price auction with a stochastic outside option.

When moves are unobservable, the unique symmetric equilibrium in a clock game is remarkably simple—each player waits a fixed amount of time after receiving a signal before making a move. Slower information diffusion leads to longer equilibrium waiting time. When moves are observable, equilibrium waiting still has the same properties up to the time the first player moves. However, following this, herding occurs—all remaining players make their move immediately.

To test the theory, we run a series of experiments designed to examine the behavioral validity of two key synchronization factors: the speed of information diffusion and the observability of moves. To the best of our knowledge, we are the first to study these questions using controlled experiments.

The main results of the experiments are:

1. Equilibrium delay is robust—we observe delay in all treatments.
2. When moves are observable, there is initial delay followed by herding.
3. The slower the information diffusion, the longer the observed delay.

The remainder of the paper proceeds as follows: The rest of this section places clock games in the context of the broader literature on timing games. Section 2 presents the model, characterizes equilibrium play, and identifies key testable implications. Section 3 outlines the experimental design, while Section 4 presents the results. Finally, Section 5 concludes. Proofs of propositions as well as the instructions given to subjects in the experiment are contained in Appendix A.

Related literature. At a broad level, clock games are a type of timing game (as defined in Osborne, 2003). As pointed out by (Fudenberg and Tirole, 1991), one can essentially think about the two main branches of timing games—preemption games and wars of attrition—as the same game but with opposite payoff structures. In a preemption game, the first to move claims the highest level of reward, whereas in a war of attrition, the last to move claims the highest level of reward.

Preemption games have been prominently used to analyze R&D races (see, e.g. Reinganum, 1981; Fudenberg and Tirole, 1985; Harris and Vickers, 1985 and Riordan, 1992). In addition, a much-studied class of preemption games is the centipede game, introduced by Rosenthal (1981). This game has long been of interest experimentally, as it illustrates the behavioral failure of backwards induction (see e.g. McKelvey and Palfrey, 1992). In clock games (with unobservable moves), private information (which leads to the de-synchronization of the clocks) plays a key role, whereas centipede games typically assume complete information.[1] Indeed, this informational difference is crucial in the role that backwards induction plays in the two games. Since there is no *commonly known* point from which one could start the backwards induction argument, this rationale does not appear in clock games.

Clock games are also related to wars of attrition, where private information features more prominently. Surprisingly, there has been little experimental work on wars of attrition; thus, one contribution of our paper is to study the behavioral relevance of private information in a related class of games. Perhaps the most general treatment of this class of games is due to Bulow and Klemperer (1999), who generalize the simple war of attrition game by viewing it as an all-pay auction. Viewed in this light, our paper is also somewhat related to costly lobbying games, see e.g. Baye et al. (1993), and the famous "grab the dollar" game, see e.g. Shubik (1971), O'Neill (1986), and Leininger (1989). Finally, the herding behavior, which is present in the clock games model with observable moves, is a feature also shared by Zhang (1997), whose model can be viewed as a war of attrition.

A recent paper by Park and Smith (2003) bridges the gap between these two polar cases by considering intermediate cases where the Kth to move claims the highest level of reward.[2] The payoff structure of our clock game is as in Park and Smith: rewards are increasing up to the Kth person to move and decreasing (discontinuously in our case) thereafter. In contrast to Park and Smith, who primarily focus on complete information, our concerns center on the role of private information and, in particular, on how private information results in de-synchronized clocks.

The key strategic tension in clock games—the timing of other players' moves—figures strongly in the growing and important literature modeling currency attacks. The recent currency attack literature has focused on static games. Second generation models of self-fulfilling currency attacks were introduced by Obstfeld (1996). An important line of this literature begins with Morris and Shin (1998), who use Carlsson and van Damme's (1993) global games technique to derive a unique threshold equilibrium. The nearest paper in this line to clock games is Morris (1995), who translates the global games approach to study coordination in a dynamic setting.[3]

As was described above, the clock games model is the finite agent analog to the models in Abreu and Brunnermeier (AB) (2002, 2003), who study persistence of mispricing in financial markets with a continuum of informationally small, anonymous traders.

[1] An important exception is Hopenhayn and Squintani (2006), who study preemption games in an R&D context where each firm's technological progress is stochastic and privately known.

[2] See also Park and Smith (2004) for leading economic applications of this model.

[3] The approach of Morris and Shin (1998) has spawned a host of successors using similar techniques as well as a number of experimental treatments (see, for instance, Heinemann et al., 2004 and Cabrales et al., 2002).