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Coordination in a changing environment[☆]

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ABSTRACT

In this article we consider a model where boundedly rational agents choose both which coordination game to play and what action to take in that game, when their information and mobility are limited and changes over time. We completely characterize both short-run and long-run outcomes. There are multiple types of short-run predictions in which agents may be at different locations, taking different actions. In the long-run, however, all agents are at the same location and take the same action in that game. The long-run prediction is unique and globally efficient most of the time.

1. Introduction

Many theoretical models have multiple equilibria. The most common examples are coordination games. Evolutionary game theory has proven useful for providing conditions for selection between Pareto efficient and risk-dominant equilibria, see, for example, Kandori et al. (1993), Young (1993), Young (1998), Ellison (1993), Blume (1993), Robson and Vega-Redondo (1996), Samuelson (1997), Vega-Redondo (1997), Fudenberg and Levine (1998).

In this article, we assume that boundedly rational agents can choose what game to play from multiple, different 2 × 2 coordination games, but the set of games an agent can choose from might change over time. For example, consider the early settlement in Polynesia (1300–900 BC), which is comprised of different islands with various resources. As such, the strategic situation tribesmen faced regarding hunting collectively or individually may be different across islands. Further, from one island tribesmen could be able to see other islands and may – or may not – paddle in canoes to a neighboring island.[1] Hence, tribesmen stochastically received information and ability to migrate to another island and choose to either hunt collectively or individually.[2]

This example helps to illustrate the setting we model, where coordination games are situated at different locations, which are connected via some network. Agents play a game with other agents at the same location. In each period an agent only receives information about the play at games in her neighborhood: she learns the distribution of play at her present location

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[1] Knowledge of and ability to travel to other islands depended, among other things, on the weather which changed over time. Indeed, in the case of Polynesian tribesmen, mobility was not symmetric, as naval technology precluded sailing against the wind.

[2] See Bellwood (1987), Dye and Steadman (1990), and Anderson et al. (2006).

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and all locations connected to her present location. Afterwards, she chooses both what game to play in her neighborhood and what action to take in that game. Each period, a new network structure is randomly realized connecting games and each agent again observes information about how play has occurred in her new neighborhood and best replies accordingly. Both information and mobility are heterogeneous, limited and change over time.[3] With this framework, we investigate efficiency and network design: what types of outcomes are expected in the short- and long-run. How does the structure of information and mobility affect outcomes? We are motivated by two stylized observations: (i) that different games (usually) have *different payoffs* and (ii) knowledge of one's environment is often incomplete and *changes over time*.

In the model, we assume that there exists a unique efficient equilibrium. Without loss of generality, we assume that this equilibrium is in the game at location 1. First, we consider a situation when each network structure has a positive probability to occur every period (a *full-support* assumption). With multiple agents and multiple locations, there are many possible configurations of agents at different locations. When agents deterministically best-reply to their environment, we characterize all short-run outcomes. In doing so, we identify three types of stable configurations: a *pure convention* in which all agents are at the same location and take the same action in that game; a *half&half convention* in which exactly half of the agents at a location take one action and the other half takes the other action; and a *mixed convention* in which multiple locations are occupied, only one action is played at a single location, and at all other locations each action is played by exactly half of the agents (at that location). Theorem 1 characterizes short-run outcomes and shows these three arrangements are the only ones possible. Unlike earlier work, which typically finds only pure conventions to be short-run outcomes, in our model agents may be dispersed at multiple locations, with different actions being taken in the short-run.

We next assume that with some small probability agents make errors, and instead of myopically best-replying, choose a strategy at random. It turns out that the globally efficient equilibrium is the long-run prediction except when location 1 "dominates" all other locations (both equilibrium payoffs are higher at location 1 than equilibrium payoffs at any other game). In this case, one of the equilibria at the "dominant" location 1 is the long-run outcome (Theorem 2). This means that the long-run prediction is either the globally efficient equilibrium or the "almost" globally efficient equilibrium. The expected time for agents to settle on a long-run outcome plays a central role in our analysis. We show that the speed of convergence to the globally efficient outcome is surprisingly fast: the expected waiting time is of the order ε^{-1}, where ε is the mistake probability (Theorem 2).

The full-support assumption plays a crucial role for the previous result. We next relax this assumption and analyze a situation when a family of networks can arise. Obviously, the information structure is the key component which determines long-run outcomes. However, if the stochastic network structure satisfies a condition we call *efficient visibility* - which means that more efficient locations are visible from less efficient locations in some network realizations - then there still exists a unique long-run prediction. This long-run outcome is either the globally efficient convention or "almost" globally efficient convention (Theorem 3). Further, we introduce a *minimal connectivity* condition, which ensures that the most efficient equilibrium outside of location 1 is visible from location 1 in some network realizations. Minimal connectivity and efficient visibility conditions guarantee that if the payoff in the most efficient equilibrium outside of location 1 is equal to or greater than the payoff at the inefficient equilibrium at location 1, then not only is the globally efficient convention the long-run outcome, but also the expected waiting time is at most of the order ε^{-1} (Theorem 4). In addition, the efficient outcome may be the single long-run prediction *even when* the payoff in the most efficient equilibrium outside of location 1 is *less* than the payoff at the inefficient equilibrium at location 1, thought the wait time in this case is longer (Theorem 4). To derive our results we employ Ellison's (2000) technique of identifying long-run stochastically stable outcomes.

Most closely related to the current paper is work studying mobile agents endogenously forming local interactions. Such work often considers coordination games, for example Oechssler (1997), Dieckmann (1999), Ely (2002), and Bhaskar and Vega-Redondo (2004). A commonality in this work is the idea that agents may move among various locations where they play the same 2 × 2 symmetric coordination game. Importantly, this means efficient outcomes exist at multiple locations unlike our setting, in which there is a unique efficient equilibrium. Oechssler (1997) assumes that agents know the relative frequencies of actions taken at all locations in the previous period and are randomly matched to play only with other agents at their respective locations. He shows that all agents take the same action in the short-run, but they may be at multiple locations. By contrast, Dieckmann (1999) relaxes full observability and studies local information and limited mobility. His agents imitate success and only imperfectly observe play at locations other than their own. Importantly, the stochastic realization of information has full support in his model. Dieckmann finds that in any absorbing state all agents are at the same location and take the same action in that game. He shows that a stochastically stable state is efficient. Ely (2002) assumes a finite number of connected locations. His agents are randomly matched with other agents at locations connected to their own location and they know the number of agents taking each action at all locations. Ely finds that all agents take the same action in the short run. He also shows that all agents take the efficient action in the long run. Bhaskar and Vega-Redondo (2004) assume asynchronous opportunities to adjust locations and actions at 2 × 2 symmetric coordination games. They obtain coexistence of conventions.

Two features distinguish our model from this earlier work. First, we relax the assumption that each location contains the same game and instead assume that different games are at different locations. Second, we allow information to change over

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[3] Our model hence incorporates elements from evolutionary game theory as well as from the networks literature.