Journal of Economic Dynamics & Control 58 (2015) 19–33

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Learning and coordination with dispersed information

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ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form
22 May 2015
Accepted 29 May 2015
Available online 20 June 2015

JEL classification:
C62
C73
D83

Keywords:
Learning
Heterogeneity
Dispersed information
Interaction
Coordination

ABSTRACT

We analyse adaptive learning in a model of incomplete and dispersed information, with externalities and strategic interactions. We build on the framework proposed by Angeletos and Pavan (2007a) and extend it to a dynamic multi-period setting where agents need to learn to coordinate. We derive conditions under which adaptive learning obtains in such setting and show that, when actions are strategic substitutes, the information structure affects the speed of convergence: while more precise private information is beneficial, better public information has negative effects. We also show that adaptive learning dynamics converge to the Bayesian Nash equilibrium, which means that agents can learn to act strategically by relying only on observable (exogenous) information.

1. Introduction

In recent years a growing literature has analyzed macroeconomic models under learning dynamics (for an authoritative treatise, see Evans and Honkapohja, 2001). While the usual practice is to assume that agents have complete information about the relevant exogenous variables that affect the economy (though they might be required to underparameterize their forecasting model, as in Branch and Evans, 2006), in reality agents cannot always perfectly observe such variables and can only rely on imperfect and noisy signals.

Behind a macroeconomic model there is often hidden, at the micro level, a component of coordination. This tension between micro coordination and macro outcomes is easily resolved under the assumption of rational expectations, which deliver a fixed point in the coordination problem. But once agents are deprived of full rationality, as it happens in the learning literature, and are moreover allowed to be heterogeneous, the issue of coordination becomes critical and its solution is connected at a deep level with the learning activity of agents and the dynamics of their beliefs.

A typical example is Muth's (1961) model of price dynamics, where firms need to coordinate their production decisions based on information conveyed by prices. Carton and Guse (2014) consider a game theoretic version of this model, and show how adaptive learning and replicator dynamics learning can give rise to rather different outcomes when firms have a discrete set of possible production levels. The learning mechanism used by agents therefore affects the solution to the coordination problem implicit in their production decisions.

The aim of the present work is to consider a setting where agents need to forecast other agents' actions in order to make their own decisions, but can only rely on imperfect and noisy signals about the state of the economy. To this end, we use a setting proposed by Angeletos and Pavan (2007a), which neatly captures the need for agents to forecast other agents' actions

http://dx.doi.org/10.1016/j.jedc.2015.05.019
0165-1889/

in order to maximize their own utility. The model, under full information and homogeneity, is isomorphic to Muth's cobweb model, whose stability conditions under learning are well known. In this work, we extend such analysis to the case with heterogeneous preferences and dispersed information.

In a model where individual utility depends not only on a fundamental of the economy but also on the aggregate action in the population, agents need to anticipate other people's behavior in order to decide their own action. In such setting, we investigate whether agents can learn to coordinate on the best strategy using adaptive learning when information sets and preferences are heterogeneous.

In order to model heterogeneous information sets, we borrow from the global games literature and assume that the fundamental itself is not observable to agents but that they have access to noisy private and public signals about such fundamental. Given this information, agents need to chose their optimal action, taking into account the fact that everybody else in the economy is also doing the same.

Note that the issue of coordination becomes relevant when agents have different information sets and/or different preferences. With homogeneous information and preferences, in fact, if agents have the same priors and use the same learning mechanism (as in most learning literature), their beliefs (and therefore actions) remain coordinated over time. It is not so if agents instead observe different information sets, as this will generate heterogeneous beliefs and therefore actions. The issue of coordination becomes then important.

The framework we propose will allow us to investigate the interaction between the problem of learning, as usually addressed in the macro literature, and that of coordination. We will show how adaptive learning can in fact act as a coordination device in a model with heterogeneous information and strategic interactions. The key parameter that governs learnability will turn out the be the private value of coordination: only if agents don't overreact to the expected actions of others, they will be able to coordinate on an equilibrium. Moreover, when actions are substitutes, the precision of information affects the speed of convergence of the mean learning dynamics.

Interestingly, adaptive learning can guide agents towards the Bayesian Nash equilibrium of the model, without them needing any knowledge of the strategic nature of the game or the structure of information but solely relying on observable data in the economy. This key result shows how powerful this mechanism is in guiding agents' actions towards equilibrium.

1.1. Related literature

Our contribution is related and builds on a number of works, and it merges concepts from different strains of literature. In terms of the framework used, the most directly related work is Angeletos and Pavan (2007a), who introduce a general setting in which agents' best actions depend on the aggregate action in the economy, and agents must solve a coordination problem in order to maximize their utility. They find that the value agents attach to coordination is crucial in determining the equilibrium and welfare properties of the economy.

The information structure for our economy is borrowed from the literature on global games, i.e., coordination games of incomplete and heterogeneous dispersed information. Morris and Shin (1998, 2001) famously showed that some degree of uncertainty about the fundamentals can be beneficial as it solves the problem of multiple equilibria in the economy. Angeletos et al. (2007) then extended the static framework of global games to allow agents to take (binary) actions repeatedly over many periods and to learn about the underlying fundamentals: they show that in this dynamic setting multiplicity of equilibria can emerge under the same conditions that would guarantee uniqueness in the static benchmark. We will not touch upon this aspect in the present work and only focus on a setting where there is a unique fundamental symmetric equilibrium for the economy.

The spirit of the paper is close to several works in the game theoretical literature, though it takes a more macro oriented approach. Marimon and McGrattan (1992), in a critical review of adaptive learning in repeatedly played strategic form games, show that if agents use adaptive learning rules with inertia and experimentation, the strategy played converges to a subset of rationalizable strategies. Beggs (2009) considers adaptive learning in Bayesian games with binary actions, a framework that includes many of the applications of the theory of global games, and presents conditions under which convergence obtains. Crawford (1995) shows how results from experiments in coordination games can be explained by assuming that agents learn to coordinate using simple linear adjustment rules.

Also relevant to our work is the literature on coordination and higher order beliefs, though we leave the explicit consideration of such a problem in the contest of adaptive learning to future research. Important and related works in this area are Townsend (1983) and Marcet and Sargent (1989): in the former, firms face the problem of forecasting the forecasts of others, and this gives rise to an infinite regress problem which is then solved by Marcet and Sargent (1989) by using adaptive learning to compute the relevant equilibrium for the model.

1.2. Plan of the paper

The plan of the paper is as follows: Section 2 introduces the basic model and shows the symmetric equilibrium under full information and rationality; Section 3 introduces learning when there is full information about the fundamental but uncertainty about other agents' actions; Section 4 analyzes learning when there is incomplete and dispersed information about the fundamental; Section 5 discusses the main results of the paper; and Section 6 concludes.