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## Global analysis of an expectations augmented evolutionary dynamics

Angelo Antoci<sup>a</sup>, Antonio Gay<sup>b</sup>, Massimiliano Landi<sup>c,\*</sup>, Pier Luigi Sacco<sup>d</sup>

<sup>a</sup> *Dipartimento di Economia, Impresa, Regolamentazione, Università degli Studi di Sassari, Via Torre Tonda, 34 – 07100 Sassari, Italy*

<sup>b</sup> *Dipartimento di Scienze Economiche, Università degli Studi di Firenze, Via delle Pandette, 9 – 50127 Firenze, Italy*

<sup>c</sup> *School of Economics, Singapore Management University, 90 Stamford Road, Singapore 178903, Republic of Singapore*

<sup>d</sup> *Dipartimento delle Arti e del Disegno Industriale, Università IUAV di Venezia, Dorsoduro 2206, 30123 Venezia, Italy*

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### ABSTRACT

We consider a deterministic evolutionary model where players form expectations about future play. Players are not fully rational and have expectations that change over time in response to current payoffs and feedback from the past. We provide a complete characterization of the qualitative dynamics so induced for a two strategy population game, and relate our findings to standard evolutionary dynamics and equilibrium selection when agents have rational forward looking expectations.

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## 1. Introduction

In an evolutionary game, players typically have no reason to care about future rounds of play. But in some cases this assumption is not reasonable: in particular, when commitments of any sort take place (think, for example, of switching costs, or investment decisions), they have reason to be concerned about the future consequences of their current actions.

Starting from this premise, an increasing amount of literature is dealing with the issue of equilibrium selection under rational expectations in normal form games. The leading contribution is by Matsui and Matsuyama (1995) (MM henceforth). They consider an infinitely repeated two-by-two coordination game with random matching in which players can only change action at a random rate (friction). Therefore, players need to form expectations about the future evolution of play within the

\* Corresponding author. Tel.: +65 6828 0872; fax: +65 6828 0833.

E-mail addresses: [angelo.antoci@virgilio.it](mailto:angelo.antoci@virgilio.it) (A. Antoci), [antonio.gay@unifi.it](mailto:antonio.gay@unifi.it) (A. Gay), [landim@smu.edu.sg](mailto:landim@smu.edu.sg) (M. Landi), [sacco@iuav.it](mailto:sacco@iuav.it) (P.L. Sacco).

population. MM show that when the friction gets smaller, a unique equilibrium is selected, the risk dominant one (in the sense of Harsanyi and Selten). In a similar fashion, Burdzy et al. (2001) analyze a stochastic evolutionary model in which players play a two-by-two game with strategic complementarity, whose payoffs change over time. They consider the same sort of friction in players' ability to change strategies and find that the risk dominant equilibrium is played at any point in time when the friction is sufficiently small.

A departure from perfect foresight was taken first by Matsui and Rob (1992). They consider a game with stochastic overlapping generations of players whose actions are fixed for the entire life cycle. Players may have heterogeneous beliefs about the future evolution of play, and their individual behavior has to be rationalized by one of them. They find, among other things, that the Pareto efficient equilibrium can be the unique globally absorbing state. Lagunoff (2000) considers an infinitely repeated common interest game in which players play self-fulfilling equilibria. His model is close to Matsui and Rob (1992) in all the other features. It is shown that the Pareto dominant equilibrium is a globally absorbing state of the dynamics when there are relatively small inertia and discounting. More recently, Matsui and Oyama (2006) consider the same setup as in MM but move away from perfect foresight by assuming rationalizable expectations. They find that, when the level of friction is small enough, and players are playing a generic two-by-two game, the risk dominant equilibrium is the unique stable set of their dynamics.

In all these works, the main emphasis is on the limit properties of the absorbing states of the evolutionary dynamics in normal form games when a random parameter (typically describing the friction in the process of strategy adjustment) becomes arbitrarily small.

Our main departure from the literature is, in line with the trend from new, more recent work, that we stick to bounded rationality. Moreover, we provide an explicit equation for the evolution of expectations. Specifically, players follow an adaptive expectation formation mechanism, whose dynamics depend only in part on how players tend to extrapolate the current outcomes into the future. We provide a global analysis of the induced (deterministic) dynamics as a function of the parameters governing the dynamics of expectations. In particular, we find that for any initial strategy distribution, the system can converge to any (if more than one) asymptotically stable fixed point, for a suitable choice of the initial value of the payoff expectations (Theorem 1). Moreover, starting from the same initial pair of strategy configuration and values of expectations, the dynamics may lead to different (if more than one) asymptotically stable fixed points depending on the values of the parameters that regulate the expectation formation process (Theorems 2 and 3).<sup>1</sup>

Indeterminacy of the equilibrium selection is not novel. For example, both MM and Matsui and Oyama (2006) obtain it when the friction parameter is large enough. Yet, our formalization of the model allows for a (non-trivial) global qualitative analysis of the evolutionary dynamics. Moreover, our approach departs from MM and Matsui–Oyama in some other respects. We consider a population game rather than a random matching setting, and assume a substantially lower degree of rationality even with reference to the Matsui–Oyama rationalizable framework, in that we simply postulate an adaptive expectations revision mechanism, without further restriction on the nature of initial expectations. In addition, the critical parameters in our framework are the ones that determine the dynamics of expectations rather than the degree of friction, and although they may present some analogies, they imply different behavioral processes. Given these premises, it is interesting to point out that in our framework, that is significantly less demanding in terms of the players' degree of rationality, no specific focal role for risk dominance emerges.

Finally, by including a specific equation for the evolution of the expectations, we can also address the issue of long run consistency of expectations.<sup>2</sup> Along this line of research, Hommes (1998) analyzes the consistency to rational expectations of backward looking expectations in a cobweb

<sup>1</sup> The distinction between history dependence and the role of expectations in selecting equilibria has been studied in the macroeconomics literature, with a focus on rational expectations (see for example, Matsuyama (1991); Krugman (1991) and Diamond and Fudenberg (1989)).

<sup>2</sup> The problem of convergence of bounded rationality to rational expectations is at the heart of learning in macroeconomics. See for example, Sargent (1993) and Evans and Honkapohja (2001).

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