Physica A 389 (2010) 3565–3571

Contents lists available at ScienceDirect

Physica A

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

Asymmetric information and macroeconomic dynamics

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ARTICLE INFO

Article history:
Received 11 February 2010
Received in revised form 22 April 2010
Available online 6 May 2010

Keywords:
Macroeconomics
Asymmetric information
Fisher information
Productivity

ABSTRACT

We show how macroeconomic dynamics can be derived from asymmetric information. As an illustration of the utility of this approach we derive the equilibrium density, non-equilibrium densities and the equation of motion for the response to a demand shock for productivity in a simple economy. Novel consequences of this approach include a natural incorporation of time dependence into macroeconomics and a common information-theoretic basis for economics and other fields seeking to link micro-dynamics and macro-observables.

1. Introduction

Asymmetric information is a powerful explanatory concept that underpins much of the success enjoyed by information economics in describing the structure and function of economic systems [1–3]. In addition to this descriptive success, however, we have shown that the dynamical law of an investment process (Tobin's Q theory) can be derived from a formalized expression of asymmetric information [4,5]. This suggests that asymmetric information can be used to derive the dynamic and equilibrium states of macroeconomic systems and the purpose of this paper is to demonstrate that this is true.

The basis for our approach is the recent reformulation of macroeconomics in terms of statistical mechanics [6]; a synthesis and extension of earlier work [7–10] showing that macroeconomics, like statistical mechanics, is probability theory with constraints [11]. This commonality, despite the manifest differences between economics and the natural sciences,[1] suggests a more fundamental common basis for the success of this and other applications of statistical mechanics in economics,[2] and it is our view that this fundamental common basis is information theory. The information-theoretic basis of statistical mechanics[3] shows how constrained probability can be used to link micro-densities with macro-observables and provides theoretical justification for a broad application of the methods of statistical mechanics that have proved remarkably effective in explaining physical phenomena.

It is our view that all things economic are information-theoretic in origin: economies are participatory, observer participancy gives rise to information and information gives rise to economics.[4] Dynamical laws follow from a perturbation of information flow which arises from the asymmetry between J, the information that is intrinsic to the system and I, the measured Fisher information of the system: a natural consequence of the notion that any observation is a result of the $J \to I$

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1 These are discussed at some length in Ref. [12].

2 See, for example Refs. [4,5,13–33] and the references therein

3 See, for example, the collection of articles in Ref. [34], especially Refs. [35,36], as well as Refs. [37–41].

4 This is similar to the Wheeler program [40,42,43] which posits the same view toward physics.

0378-4371/$ – see front matter
doi:10.1016/j.physa.2010.04.032

information-flow process. In this manner macroeconomic dynamics are a natural consequence of our information-theoretic approach. This is of particular relevance to macroeconomics where notions of dynamics and disequilibrium do not arise naturally in traditional treatments.[5]

We explore this approach below by deriving the equilibrium distribution, non-equilibrium distributions, and dynamical law linking them for productivity in a simple economy. We begin in Sections 2.1 and 2.2 with a review of this economy together with a derivation of the equilibrium distribution associated with this economy that follows from the use of Shannon information. As this derivation is both a straightforward application of Jaynes' statistical mechanics (see footnote 3) and has appeared in the economics literature [6,9], it provides a widely accessible introduction to the model and variational formalism to follow. Next, in Section 2.3, we show that by replacing Shannon information with Fisher information a Schroedinger equation arises from the variational formalism which yields both equilibrium and non-equilibrium distributions. Furthermore, using the well-known relationship between the Schroedinger and Fokker–Planck equations an equation of motion based on these distributions follows immediately, thus providing an information-theoretic basis for use of Fokker–Planck equations that has appeared in macroeconomics [6–10] and a natural general way of incorporating dynamics in economics. This formalism is illustrated in Section 2.4 by calculating the equilibrium and non-equilibrium productivity distributions for a simple economy. We close in Section 3 with a discussion and summary.

2. Macroeconomic equilibrium and dynamics

2.1. The macroeconomy

Following the discussion in Ref. [6,9] we consider an economy with S sectors, each of size n_s where $s = 1, \ldots, S$. The economy is endowed with total production factor N divided amongst each sector which results in the resource constraint

$$\sum_{s=1}^{S} n_s = N. \tag{1}$$

Each sector produces output Y_s

$$Y_s = c_s n_s, \tag{2}$$

where c_s is the productivity of sector s. Productivity differs across sectors and we order the sectors such that $c_1 < c_2 \ldots < c_S$. The total output of the economy, or gross domestic product (GDP), is the sum of the output from each sector

$$Y = \sum_{s=1}^{S} Y_s = \sum_{s=1}^{S} c_s n_s. \tag{3}$$

Assuming the total output Y to be equal to the exogenously given aggregate demand $\widetilde{D}$ we have that

$$\sum_{s=1}^{S} c_s n_s = \widetilde{D}. \tag{4}$$

Dividing Eqs. (1) and (4) by N we obtain

$$\sum_{s=1}^{S} p_s = 1, \tag{5}$$

$$\sum_{s=1}^{S} c_s p_s = D, \tag{6}$$

where $p_s \equiv n_s/N$ and $D = \widetilde{D}/N$. Interpreting p_s as a probability, we see in Eq. (5) the standard requirement that probabilities sum to unity and in Eq. (6) that the average sector productivity is equal to the aggregate demand per unit of factor endowment. The question of how to calculate the probability consistent with Eqs. (5) and (6) is the issue to which we now turn.

2.2. Shannon information

Probability distributions $p(x)$ implicit in observed data $d_1, \ldots, d_M = \{d_m\}$ that can be expressed as averages of known functions $\{f_m(x)\}$:

$$\int f_m(x) p(x) \mathrm{d}x = d_m, \quad m = 1, \ldots, M, \tag{7}$$

[5] See, for example, Refs. [44–46] and references therein.