Physica A 389 (2010) 287–295

Contents lists available at ScienceDirect

Physica A

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

# Asymmetric information and economics

B. Roy Frieden, Raymond J. Hawkins *

*College of Optical Sciences, University of Arizona, Tucson, AZ 85721, USA*

ARTICLE INFO

*Article history:*
Received 25 April 2009
Received in revised form 5 August 2009
Available online 17 September 2009

*PACS:*
89.65.Gh
89.70.+c

*Keywords:*
Asymmetric information
Fisher information
EPI
Economics
*Q* theory
Market efficiency

ABSTRACT

We present an expression of the economic concept of asymmetric information with which it is possible to derive the dynamical laws of an economy. To illustrate the utility of this approach we show how the assumption of optimal information flow leads to a general class of investment strategies including the well-known *Q* theory of Tobin. Novel consequences of this formalism include a natural definition of market efficiency and an uncertainty principle relating capital stock and investment flow.



## 1. Introduction

Information flow is central to economic activity and a primary causal factor in the emergence, stability and efficiency of capital markets [1–3]. The interaction between information and economic agents in the price discovery process suggests that information flow may also play a central role in determining the dynamical laws of an economic system, and it is the purpose of this paper to demonstrate that this is, in fact, the case.

The central role for information in economic theory was established by the field of information economics that developed in reaction to the competitive general equilibrium view, represented by Debreu [4] and Arrow [5], which took information as given and perfectly known. Information economics replaced this view with one where information is imperfect, costly to obtain and where asymmetries of information play a fundamental role. The origin of information economics is seen in the work of Stigler [6,7] who studied the role of information in ascertaining market prices and in the labor market.[1] In this work Stigler observes that price dispersion is a ubiquitous manifestation of market ignorance, that markets and advertising can decrease the cost of measuring and the size of this dispersion, and that information gained about a market is capital produced at the cost of search. Stigler's work was soon followed by that of Akerlof [11], Spence [12] and Rothschild and Stiglitz [13] which are considered to be the foundation of information economics. Akerlof's examination of the relationship between quality and uncertainty introduced the notion of asymmetric information – the situation where one party in a transaction has more information than the other concerning the quality of the merchandise – and the importance of this notion to the function of markets. Spence, like Stigler before him, examined information in the job market where information asymmetry favors the job applicant over the prospective employer. Spence also introduced the important notion of informational equilibrium in contrast to that of the general equilibrium view mentioned above.

* Corresponding author. Tel.: +1 415 254 0788.
*E-mail addresses:* roy.frieden@optics.arizona.edu (B.R. Frieden), rhawkins@optics.arizona.edu (R.J. Hawkins).

[1] Information had, of course, been discussed in economics before this time, but as Stiglitz points out (see, [1–3] and the references therein), information was not formally part of economic theory before this time. An example of this is seen in the work of Hayek [8–10] where the problems of information in economics are discussed in some detail but a theory to deal with this is not presented.

0378-4371/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2009.09.028

The full impact of information in economic theory was then advanced by Rothschild and Stiglitz who observed that "some of the most important conclusions of economic theory are not robust to considerations of imperfect information." In their examination of the market for insurance they found that small amounts of imperfect information have a significant effect on markets, that the structure and existence of equilibrium depended on the nature of information imperfections and that in some cases equilibrium would not exist. These implications of informational imperfection and asymmetry for the insurance market were followed in rapid succession by closely related studies focussing largely on markets. In stock markets it was found that a certain amount of noise is essential for market stability and that if information is costly that markets cannot be informationally efficient [14,15]. Futures markets were reinterpreted as "a place where information is exchanged and where people who collect and analyze information about future states of the world can earn a return on their investment in information gathering" [16]. These results were, in turn, incorporated into a general representation of information in capital markets in which the role of information in market breakdown was reaffirmed and the fundamental conflict between the nature of information that a market price system should convey and the cost of acquiring that information by market participants was brought into focus [17,18]: if a price system perfectly reflects information, what incentive is there for participants to collect costly information to feed into the price system? A similar synthesis was seen in the analysis of credit markets where the problem of incomplete and asymmetric information was shown to give rise to credit rationing [19].

These advances in the incorporation of information into economic theory are also remarkable in that they have been accomplished without reference to an information measure. The manner in which the literature of information economics has evolved, however, suggests that the Fisher information measure could be of considerable value in unifying many economic concepts [20]. First, throughout this literature the probability distribution has played a central role in information economics, and dispersion or variance often appear as alternative measures of relative information.[2] This perspective is anticipated by Fisher who identified information with the inverse of the variance.[3] Second, cost plays a central role in design both in the work of Fisher [4] and the information economics literature. Third, efficiency is a central concept related to asymmetric information which appears in information economics, in Fisher's use of information and in recent advances of the Fisher information measure.[5] Finally, recent advances in macroeconomics suggest a natural role for techniques traditionally associated with statistical mechanics [24] and recent advances in information physics have shown that Fisher information provides a natural framework for this approach [20].

Our view is that all things economic are information-theoretic in origin: economies are participatory, observer participancy gives rise to information and information gives rise to economics.[6] In particular, the dynamical laws of an economy arise out of a perturbation of asymmetric information where asymmetric information is defined as the difference between the measured $I$ and intrinsic $J$ levels of Fisher information in an economic system. The notion that dynamical laws follow from information begins with the idea that any observation is the result of an information-flow process $J \rightarrow I$ where $J$ is the information that is *intrinsic to* the system (the present, most complete and perfectly knowable collection of information concerning the system that is relevant to the measurement exercise) while $I$ is the information about the system based solely upon observations, i.e. the information that is in the data. Remarkably, if $I$ and $J$ are formalized as *Fisher* information, extremizing[7] the asymmetric information $(I - J)$ has been shown to yield dynamical laws for physical systems [20] and it is the purpose of this paper to demonstrate that this holds true in economics. This will be illustrated below where we show how, when applied to a canonical investment problem, asymmetric information $(I - J)$ becomes the integral expression of Tobin's $Q$ theory of investment.[8]

To this end we continue in Section 2 of this paper with a traditional derivation of Tobin's $Q$ theory both to define terms and to set the theoretical context for the presentation of our information-theoretic derivation in Section 2.2. We then discuss the investment strategies that follow from our information-theoretic approach and in Section 2.3 identify the one associated with Tobin's $Q$. This leads naturally in Section 2.4 to a discussion of economic efficiency in general and of market efficiency in particular. Finally, we review these results and their implications in Section 3.

## 2. Asymmetric information economics

### 2.1. Q theory: Traditional derivation

The $Q$ theory of investment is a canonical model in macroeconomic investment that describes a firm seeking to maximize its net present value by investing some of its net income in income-generating capital stock (e.g. manufacturing machinery)

2 For example, "the equilibrium ratio of information quality between informed and uninformed traders" is a ratio of variances [18].

3 See, for example, pages 184–185 of Fisher [21].

4 The interplay between cost and information is discussed throughout Fisher's work [21–23].

5 See, for example, Grossman and Stiglitz [18], section 73 of Fisher [21] and Frieden [20] respectively.

6 This can be viewed as the economic equivalent of the Wheeler program [25–27]. For a discussion of the Wheeler program and Fisher information see Plastino [28].

7 Specifically, we shall employ the variational approach known as extreme physical information (EPI) [20]. EPI has been used similarly to study societal dynamics that follow from the asymmetry arising from the difference between societal values as expressed in, for example, a constitution and the society's actual practice [29,30]. Our application of EPI in the present paper extends our earlier analysis of Tobin's $Q$ in [31].

8 Early references to $Q$ theory employed a lower-case $q$ in the description (e.g. $q$ theory or Tobin's $q$). Recent research employs the upper-case $Q$ in the description and we have adopted that convention in this paper.