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Economic modelling with low-cognition agents ☆

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Abstract

The standard socio-economic model (SSSM) postulates very considerable cognitive powers on the part of its agents. They are able to gather all relevant information in any given situation, and to take the optimal decision on the basis of it, given their tastes and preferences. This behavioural rule is postulated to be universal. The concept of bounded rationality relaxes this somewhat, by permitting agents to have access to only limited amounts of information. But agents still optimise subject to their information set and tastes.

Empirical work in economics over the past 20 years or so has shown that in general these behavioural postulates lack empirical validity. Instead, agents appear to have limited ability to gather information, and use simple rules of thumb to process the information which they have in order to take decisions.

Building theoretical models on these realistic foundations which give better accounts of empirical phenomena than does the SSSM is an important challenge to both economists and econophysicists. Considerable progress has already been made in a short space of time, and examples are given in this paper.

Keywords: Standard socio-economic model; Bounded rationality; Rule of thumb behaviour; Low cognition

1. Introduction and background: economic theory and agent cognition

The standard socio-economic science model (SSSM) assumes very considerable cognitive powers on behalf of its individual agents. Agents are able both to gather a large amount of information and to process this efficiently so that they can carry out maximising behaviour.

The SSSM postulates a universal law of agent behaviour, namely that agents always choose the optimal decision, given their particular tastes and preferences. Agents differ in these preferences, which are assumed to be fixed. But the behavioural rule which they follow is assumed to be common to all agents.

Until around 1970, almost all economic theory of agent behaviour was of this kind. Since then, economic theory has developed considerably. The developments have involved relaxations of the cognitive powers ascribed to agents in the SSSM, namely the ability to gather full information and to make the optimal decision given this information and their tastes and preferences.

A very influential strand within economics over the past 30 years has been the concept of bounded rationality, introduced by the 2001 economics Nobel prize winners Akerlof and Stiglitz (e.g., Refs. [1,2]). This

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retains the universal behavioural postulate of optimising agents of the SSSM. However, the assumption that agents have complete information is relaxed. Agents only have partial information, and the amount of information in an otherwise identical setting may vary across agents.

More recently, a more general approach to agent behaviour has begun to be used. It is sufficiently recent as to not yet have an agreed descriptive phrase to summarise it. It is sometimes described as 'behavioural economics', sometimes as 'agent-based modelling', sometimes as 'evolutionary economics', and other phrases are occasionally used. Agents not only have incomplete information, but are no longer postulated to follow optimising behaviour given the available information and their tastes and preferences. Instead, they use rules of thumb. In addition, the tastes and preferences of agents may not be fixed, but may be altered by the behaviour of others (Refs. [3,4] are early examples of this).

The discipline of experimental economics underpins this approach. The key figures in this have been the 2002 Nobel prize winners Khaneman and Smith [5,6]. This has involved testing empirically how agents actually behave in practice. In general, except in simple situations in which the amount of information to be processed is relatively low, agents in practice tend not to follow the behavioural postulate of the SSSM (Refs. [5,6] and the extensive references in these two articles).

A very important implication of this approach is that the assumption of a universal rule of agent behaviour is abandoned. The rules of thumb which describe agent behaviour in one context may differ from those which describe it in another, even for the same agent. As Akerlof puts it 'in this new style [of economics], the economic model is customized to describe the salient features of reality that describe the special problem under consideration' [7].

A special case of behavioural economics, the term we will use in this paper for this approach, is one in which agents are postulated to have zero cognitive ability. In other words, they neither gather nor process information, but instead take decisions purely at random. An early example of this is Ref. [8]. Economists of all persuasions, even of the behavioural school, tend not to be sympathetic to this postulate. The concept that agents respond to incentives is essentially common to the three approaches described above. Under the SSSM postulates, agents respond to incentives in the optimal way given their tastes and preferences. In the behavioural approach, agents may consistently take decisions which are poor, which are short-sighted and which might actually turn out to work against their own self-interest. But at the time they take the decision, they believe they are acting to enhance their self-interest (again, with the tastes and preferences they happen to have at the time).

2. Low-cognition models

Khaneman in his Nobel lecture [5] noted that 'incorporating a common sense psychology of the intuitive agent into economic models will present difficult challenges, especially for the formal theorist'. The challenge is twofold. First, to develop models which are based on more realistic rules of agent behaviour. Second, to give better empirical accounts of economic (and social) phenomena with such rules than either the SSSM or its extension into bounded rationality are capable of.

Progress is being made. For example, there are several well-known examples of competition between rival variants of new technologies in which a dominant market share is obtained by a product which performs less well than its competitors. This is difficult to explain under the SSSM, because agents are presumed to operate with full information and to take the optimal decision. Ref. [3] gives a model of agents using simple rule of thumb behaviour which is able to account for this phenomenon.

Economics, using the postulates of the SSSM, has made valuable contributions to the understanding of crime (Ref. [9] is the seminal reference). But its difficulty here is in explaining the massive variations in crime rates which are observed (e.g., Ref. [10]) both across time and across place, particularly the latter. Agents may respond to differences in positive incentives, such as non-criminal employment opportunities, and to negative incentives such as the punitive nature of the criminal justice system. But these factors vary much less, sometimes by orders of magnitude, across time and place than do crime rates. Refs. [11,12] provide behavioural models which are much more able to explain the observed ranges of crime rates. The volatility of financial markets has been described by economics Nobel laureate Kenneth Arrow as an 'empirical refutation' [13] of general equilibrium theory, the core model of the SSSM. Simple behavioural models [4,14] provide a superior account of this important empirical phenomenon.

3. An illustrative example

A key empirical feature of the market-oriented capitalist economies is persistent short-run fluctuations from year to year around a slow, underlying trend of real output growth. These short-run fluctuations in output are known in economics as the 'business cycle'. The term can be confusing to natural scientists, because it is by no means apparent from a simple time-series plot of the data that anything resembling a regular cycle exists.

Conventional economics lacks a satisfactory theory of the business cycle. It is essentially a theory about equilibrium behaviour, yet the existence of the business cycle shows that the Western economies are in a persistent state of change. Theories based on the SSSM are obliged to postulate that the cause of the cycle is a series of random shocks which are external to the economic system (Ref. [15], for example, describes the most recent theoretical approach).

These conventional theories face formidable empirical difficulties. For example, the main reason why economists speak of the 'business cycle' is because of the positive cross-correlations between the growth rates of output of individual sectors, and even of individual firms, over time [16,17]. In other words, during an economic boom most sectors and firms tend to do well, whilst in a recession most tend to do rather badly. Models based on the SSSM postulate the existence of a single 'representative agent' which receives the random external shocks. So by virtue of the approach itself, such models cannot capture the cross-correlations between many heterogeneous agents which is a key feature of reality. Further, a recent empirical study concluded that the evidence is not consistent with the hypothesis that output fluctuations are caused by technological shocks [18], the most widely cited source in the economics literature of such shocks.

Output growth over time does have distinguishing features in both the time and frequency domains. First, low positive first-order autocorrelation (around 0.4 for the US). Second, a weak concentration of the power spectrum at frequencies between 5 and 9 years. Models of the cycle based on the principles of the SSSM appear to have great difficulty in replicating these properties, as the economics profession has noted [19,20]. There is an additional feature reported in this journal in 2004 [21] which SSSM models are also unable to replicate. The cumulative size of recessions, defining recession in the standard way as a growth rate less than zero, follows an exponential distribution.

A very simple behavioural model published in this journal in 2002 [22] is able to generate close approximations to all these empirical features of the business cycle, including the property of the exponential size of recessions, discovered subsequent to the model being published.

The model is populated by firms (empirically, firms are the key determinants of the cycle), which are heterogeneous both in terms if their size (drawn from a power law distribution) and their behaviour.

The model evolves on a step-by-step basis. In each step, each agent decides its rate of growth of output for that period, and its level of sentiment about the future.

Each agent sets its rate of growth of output in period t by:

$$x_i(t) = \sum_i w_i y_i(t-1) + \varepsilon_i(t), \tag{1}$$

where $x_i(t)$ is the growth rate of output of the ith agent at time t, $y_i(t-1)$ is the sentiment of the ith agent in the previous period, and w_i is the size of each individual firm. The variable $\varepsilon_i(t)$ is a random variable drawn separately for each agent in each period from a normal distribution with mean zero and standard deviation sd_1. Its role is to reflect both the uncertainty which is inherent in any economic decision making and the fact that the agents in this model, unlike mainstream economic models which are based on the single representative agent, are heterogeneous.

In turn, the sentiment of the ith agent, $y_i(t)$ is determined by

$$y_i(t) = (1-\beta)y_i(t-1) - \beta\left[\sum_i w_i x_i(t-1) + \eta_i(t)\right], \tag{2}$$

where y_i, x_i and w_i are as defined above, and where η_i is drawn from a normal distribution with mean zero and standard deviation sd_2. The coefficient on $X(t-1)$, β, has a negative sign, again reflecting the Keynesian basis of the model [23, Chapter 22].

The agents are myopic and use simple rules of thumb to set their rates of growth of output. But from these simple rules of behaviour, the key empirical features of overall output growth emerge: positive cross-correlation of output across agents, low first order autocorrelation, weak concentration of the power spectrum at the appropriate frequency, and an exponential distribution of the cumulative size of recessions.

4. Conclusion

The standard socio-economic model (SSSM) postulates very considerable cognitive powers on the part of its agents. They are able to gather all relevant information in any given situation, and to take the optimal decision on the basis of it, given their tastes and preferences. This behavioural rule is postulated to be universal. The concept of bounded rationality relaxes this somewhat, by permitting agents to have access to only limited amounts of information. But agents still optimise subject to their information set and tastes.

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