

Beyond Copying

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Abstract

Much of the agent based/network literature which focuses on the spread of ideas/behaviour, the emergence of norms and similar phenomena, essentially involves 'binary choice with externalities'. With this model, the process of 'adoption' of new norms or shared conceptions is essentially one of copying (imitation). The same principle applies to models of preferential attachment.

We argue that in the context of the adoption of ideology/norms/concepts of quality, the model needs considerable extension to be grounded in more realistic agent behaviour. We consider models from cultural evolution and models which allow the agent to decide partly on autonomous fixed preferences. We also discuss a recent extension which proposes that agents differ in their propensities to discuss and receive information on concepts of this type. Finally, drawing on the literature on social capital, we propose that agents require repeated exposure before switching opinion on these matters, and that several steps of any model may be required.

Keywords: binary choice with externalities; preferential attachment; cultural evolution; bounded rationality

1. Background

1.1 Binary choice with externalities

Much of the agent based/network literature which focuses on the spread of ideas/behaviour, the emergence of norms and similar phenomena, essentially involves 'binary choice with externalities' (Schelling 1973, Watts 2002). Heterogeneous agents are connected on a network and can be in one of two states of the world (though this can be generalised to k states). Agents switch depending upon their individual threshold (propensity to switch) and the states of the world of their neighbours. With this model, the process of 'adoption' of new norms or shared conceptions is essentially one of copying (imitation).

The purpose of the paper is to describe various ways in which this powerful model may need to be developed when considering the emergence of concepts such as quality and social norms, rather than, say, the decision to buy a particular consumer brand or to adopt a new technology.

In the context of the adoption of new consumer products, the assumptions of the basic copying model may often be a reasonable approximation to reality. This is particularly the case in fashion-related markets. With more complex products such as savings accounts and electronic consumer durables, provided the products all meet minimum quality standards, copying the behaviour of agents on your

particular network may very well be a sensible thing to do. Such products are difficult to evaluate, and there may be high costs involved in gathering and processing the relevant information. So it is reasonable to imitate the behaviour of those whose opinions/behaviour you respect in this particular context.

A classic account of copying is what we might term the 'conformity' experiments of Asch (1953). The behaviour of an agent tends to become more similar to that of the group to which he or she belongs either because of the belief that the group possesses superior information compared to the agent, or from a desire to conform to group norms.

An important recent analysis of the power of copying as a mode of behaviour is provided by Rendell et.al. (2010). The authors observe that copying – they use the phrase 'social learning' interchangeably with 'copying' – is 'widespread in nature and is central to the remarkable success of humanity, yet it remains unclear why copying is profitable and how to copy most effectively' (p.208). They organised a computer tournament in which entrants submitted strategies specifying how to use social learning and other alternatives to acquire adaptive behaviour in a complex environment. They note that 'most current theory predicts the emergence of mixed strategies that rely on some combination of types of learning. In the tournament, however, strategies that relied heavily of social learning were remarkably successful... the winning strategy relied nearly exclusively on social learning '(p.208).

In many models of choice with externalities, the decisions of the agent are made with reference to the decisions of its local neighbourhood of agents (a classic reference is Watts op.cit.). In other words, the agent is in general connected to a relatively small number of others and lacks information on the decisions of the whole population of agents.

The process of preferential attachment (Yule 1925, Simon 1955) involves agents choosing amongst a fixed number (which may be large) of alternatives, and doing so probabilistically in proportion to the number of times each alternative has already been chosen by other agents. We can usefully think of this as corresponding to agents having complete information about the choices made by all other agents. So instead of having local information about the choices of a small number of others, the agent has global information about the choices of all agents.

A drawback of preferential attachment in its basic form is that as the process of selection unfolds and more and more agents make choices, the relative rankings amongst the alternatives becomes fixed. The point is illustrated clearly by Arthur (1989) who demonstrates the existence of fixed points in a Polya urn

process in which agents choose between two alternatives (the fixed points themselves depend upon the replacement rules which are used). Preferential attachment network models have been proposed with aging 'add-ons' (for example, Dorogovtsev et. al. 2000), where the probability of the choice itself diminishes with its age. But this seems inappropriate for the adoption of ideas or norms, where an idea does not go extinct because it is old, but because no one uses it anymore.

1.2 *The inclusion of innovative behaviour*

Cultural evolutionary theory retains preferential attachment as the basis for individual decisions amongst alternatives, but allows for agents to innovate and select something which no agent has previously done before (Shennan and Wilkinson 2001 Lieberman et al. 2005, Bentley and Shennan 2007). Agents select amongst existing alternatives using preferential attachment with probability $(1 - \mu)$ and make an entirely new choice with probability μ . There is a substantial amount of evidence from a variety of contexts that μ is small, not greater than 0.1 (for example, Eerkens 2000, Larsen 1961, Rogers 1962).

This approach creates, in a natural way, turnover in the rankings of the alternatives in terms of the numbers of agents which adopt them. It therefore seems highly relevant to concepts such as norms and quality, where the popularity of choices varies over time and where genuinely new ideas/modes of behaviour do emerge.

Bentley et.al. (2010) generalise this model even further. Instead of the preferential attachment part of agents' behavioural choice rule taking into account *all* previous choices of agents over every step of the model, the number of steps which agents take into account itself becomes a parameter of the model. This retains the property of turnover in rankings, but at any point in time the introduction of this second parameter enables a very wide variety of non-Gaussian right-skewed outcomes to be generated, such as winner-take-all, exponential, power law in the tail, and power law over the entire distribution.

The above models can usefully be applied in a wide range of practical contexts, and as noted those from the background of cultural evolution may be particularly appropriate to the emergence of norms and concepts of quality. They extend the principle of copying to allow for genuinely innovative behaviour.

We consider in the paper a further extension to the basic principle of copying. This involves the inclusion of an element of bounded rational choice along with that of the principle of copying. We illustrate this first of all with an example from consumer demand theory. We then extend the principle

to include the impact of agents being willing either to share information/beliefs with others, and/or to absorb such information when it is presented to them. We go on to consider the implications of requiring agents to experience multiple exposures to a concept or idea before they eventually adopt it.

2. Copying and bounded rational choice

In addition to using the principle of copying, agents may also operate with an element of bounded rational choice in which they form their own personal view on the desirability of adopting a particular mode of behaviour. Agents have heterogeneous preferences on the weights they assign to 'peer influence' (copying) and 'rational choice' i.e. evaluating the attributes of the alternatives in some bounded rational way. The weights will vary not only across individual agents, but in different contexts the same individual will use different weights.

Care is required to avoid the temptation of attributing outcomes in modern communications contexts in whole or even in the main to the process of copying. For example, Aral et.al. (2009) analyse a global instant messaging network of 27.4 million users, using data on the day-by-day adoption of a mobile service application and users' longitudinal behavioral, demographic, and geographic data. The authors find that more of the contagion can be attributed to homophily than to contagion. An obvious interpretation of this is that any given group of agents will have similar (fixed) tastes and preferences, and adoption patterns within groups are accounted for by these more than by imitation/copying.

An illustration of a model which includes both copying and bounded rationality is given by Michard and Bouchaud (2005). Each agent is assumed to face a binary choice, and the outcome depends upon three factors. First, the (fixed) personal opinion of the agent, ϕ_i . Second, the time dependent public information which is available, which they characterize by a function $F(t)$. Third, social pressure or imitation effects; each agent i is influenced by the decision made by a certain number of other agents j in his/her neighbourhood, v_j . The overall incentive of the agent is simply the sum of the three factors, and the agent adopts a particular mode of behavior if the sum is greater than zero, and the alternative mode if it is less than zero.

Michard and Bouchaud set the model up in such a way that its mathematical form is that of the Random Field Ising model of physics, which has been studied intensively. A key assumption required to do this is entirely reasonable in a social context, namely that the influence of an agent on another is always

positive, in other words the model does not allow for 'snob' effects in which an agent becomes less likely to adopt a particular mode of behaviour the more that other agents adopt it. They demonstrate interesting properties of the model, such as the existence of discontinuities in the overall outcome. There is a certain amount of artificiality to the model, because it is motivated by the need to derive the Random Field Ising model, but it remains an interesting example of extending simple copying to incorporate boundedly rational decisions making by agents.

3. The willingness to share and/or absorb information

In the context of the emergence of shared concepts of quality and/or norms, we cannot use the 'objective' attributes of the 'offer' such as price and quality. A more complicated extension of the basic imitation model seems to be required.

In the standard copying models such as that of Watts (op.cit.), agents are typically allocated a 'threshold'. This defines their willingness to copy the behavior of others. If the proportion of the agents to which any given agent is connected adopts a different behavior to that of the agent, the agent will itself adopt that mode.

This may very well be an element in the practical choices faced by agents in deciding on questions of how to judge concepts of quality and shared norms. However, it seems reasonable to consider that in these contexts, additional factors may be at work. Implicit in the 'binary choice with externalities' models is the assumption that it is obvious which state of the world (which choice) has been adopted by each relevant agent. Either the agent has a cell phone, for example, or he/she does not, and it is very easy information to acquire. However, in matters of ideology, beliefs and norms, agents may differ in their propensities to disclose such information. Or, alternatively, we may think of agents differing in their eagerness to spread their own particular view.

In addition, the 'rational' aspect of choice in these situations may lead to agents differing in their willingness to consider arguments/information which is put to them by other agents. This is conceptually different from the principle of copying. Agents consciously choose whether or not to consider ideas put to them by other agents.

Ormerod, Rosewell and Wiltshire (2010, forthcoming) calibrate a model of this type to data on the spread of innovation in four different industries in the Greater Manchester region of the UK. They assume that an agent adopts the 'norm' (i.e. the innovation) of the other if the willingness to be persuaded parameter assigned to the agent is greater than the willingness to persuade of the agent doing the persuading. The overall decision of an agent depends upon two factors. First, the propensity of the agent to simply imitate or copy others, and the choices made by the agents to which that agent is connected. Second, the relative weights of 'persuadability' and 'persuasiveness'.

They find that imitation is a weaker method of spreading innovation than what might be termed the 'sharing' process. Indeed, with the network structures in these particular industries, the imitation process is incapable of generating a cascade of global proportions.

A further extension is certainly worth investigating in the context of the adoption of shared conceptions of quality and norms. Particularly in the context of beliefs, the process may very well not be a simple [0,1] choice. In 16th century Europe, for example, a devout Catholic may rarely have experience a Eureka! moment, as it were, and decided there and then to become a Protestant, but various stages would have been required for the agent to convert. Coleman (1988) and Putnam (1999), for example, argue that social capital is built by the repeated interaction among actors involved in a social dilemma.

So before an agent switches from one state of the world to another, k passes through the model might be required. So the model is solved using the behavioural rules described immediately above, and the agents which switch to state 1 of the world (from the initial condition in which all are in state 0 and a small number are seeded at random to switch to state 1) are 'tagged'. The model with the same network structure is solved again, with different random seeds. We note at the end of the solution those agents which have acquired two tags i.e. have switched to state 1 in both solutions. This can continue for k states.

The effect of this is to introduce a further parameter into the model, namely k , the number of times an agent needs to switch to state 1 of the world before it is deemed to be 'converted' to this opinion. The principle could, of course, be applied to the simple copying model of binary choice with externalities.

But it does seem a potentially important extension in the context of norms and quality, which may very well require repeated interaction amongst agents.

4. Brief discussion

In many contexts, what we term the 'classic' model of binary choice with externalities is a useful way of analysing and understanding outcomes. In this model, agents either have information on, or are willing to be persuaded by, a subset of the total population of agents, the ones which they are connected to on the network. The model of preferential attachment, which is also widely used, can be thought of as not just extending choice from $[0,1]$ to a larger number of alternatives, but of being a model in which agents have knowledge of/take account of the decisions of all other agents in the population.

Both of these are valuable models, but the process by which norms/concepts of quality emerge requires the basic copying approach to be extended.

This paper both draws on the literature and suggests a further extension to be examined. An important development of the copying principle - whether binary choice or preferential attachment - is given by models of cultural evolution. These allow for the possibility of innovation in the choices which agents make. This is not only realistic in the context of the emergence of norms/concepts of quality, but generates entirely naturally turnover in the relative popularity of different outcomes.

In addition, it seems reasonable that individuals may take into account their own autonomous opinions, developed through some form of bounded rationality. Even in markets for new consumer products, recent evidence suggests that this may be empirically important.

Most models assume that the state of the world (the choice made) of agents is obvious, but, again in the context of the emergence of norms, agents may not always be willing to share their opinions with others. Or they may differ in the extent to which they want to persuade others to change their minds. Equally, agents may be more or less receptive to such efforts, a concept which is different from that of simple copying.

Finally, we suggest that agents may require repeated interaction with others before they alter their opinions on matters of ideology/social norms, and we propose a method of taking this into account.

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