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**Andrew B. Trigg*, Andrew J. Bertie, Susan F. Himmelweit**

CRESC, Open University

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For further information: Centre for Research on Socio-Cultural Change (CRESC)
Faculty of Social Sciences, The Open University,
Walton Hall, Milton Keynes, MK7 6AA, UK
Tel: +44 (0)1908 654458 Fax: +44 (0)1908 654488

Email: cresc@manchester.ac.uk *or* cresc@open.ac.uk

Web: www.cresc.ac.uk

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**Andrew B. Trigg, Andrew J. Bertie, Susan F. Himmelweit**
***Department of Economics, The Open University, U.K.***

**Corresponding Author.**

Andrew B. Trigg
Department of Economics
Faculty of Social Sciences,
The Open University,
Walton Hall,
Milton Keynes MK7 6AA UK

Tel: +44 (0)1908 65 4421/4445
Fax: +44 (0)1908 654488
a.b.trigg@open.ac.uk;

## Abstract

The contribution to the social theory of consumption of the late Pierre Bourdieu has been widely recognized, but not fully absorbed by the economics discipline. To address this lacuna, an agent-based model of Bourdieu's social theory is developed by extending Axelrod's cultural diffusion model. Bourdieu's theory is decomposed into two components: a capital effect on social interaction and an innovation effect. Whereas simulations of the capital effect are found to have a key role in the reproduction of economic inequality, by comparing survey and simulation results the innovation effect is shown to provide an insight into how cultural capital is distributed.

JEL Classification: C0, D3, Z1

**Keywords:**
Bourdieu; habitus; cultural capital; Axelrod; inequality.

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# Modelling Bourdieu: An Extension of the Axelrod Cultural Diffusion Model

## 1. Introduction

The contribution to the social theory of consumption of the late Pierre Bourdieu has been widely recognized, particularly his most well known book, *Distinction: a critique of the judgement of taste* (1984); for Campbell (1995, 103) he was 'the most important contemporary theorist of consumption proper.' [1] Even in economics, studies relating consumption to status have started to incorporate some of Bourdieu's ideas (see Reinstaller and Sanditov 2005; Swann 2001; Aversi et al 1999; Piketty 1998). The problem, however, is that these studies only scratch the surface of Bourdieu's contribution to the understanding of how inequality is reproduced in a multicultural context. In this regard, Wacquant (1992, p. 4) complained that Bourdieu's work 'has typically been apprehended and incorporated in "bits and pieces"'. Although there is an attempt to model distinction, where the rich distinguish their tastes from the poor, the analytical core of Bourdieu's system has been largely ignored. The economics discipline has not, for example, engaged with the concept of habitus, in which the tastes and preferences of agents both determine and are determined by social inequality; and there has been virtually no engagement with the concept of cultural capital.[2]

The lack of engagement with these concepts may not be surprising, given the 'allusions, gaps and glissandos' that have been identified in Bourdieu's often difficult prose (Lamont and Lareau 1988, p. 153). From an economist's perspective, it has been lamented that Bourdieu's theory 'lacks the power of a quantitative modelling framework' (Cowan et al 1997, p. 717). The main contribution of this paper is to develop a quantitative model of Bourdieu's theoretical approach. This model is intended both to be accessible to an economics audience, and to contribute to quantitative sociology. One of the advantages of Bourdieu's approach is that by using the concept of 'capital' he makes a concerted effort to bridge the divide between sociology and economics (see Svendsen and Svendsen 2004). By quantifying Bourdieu's approach, a direction of synthesis between these two disciplinary strands is also suggested.

Agent-based modelling provides a possible starting point for developing a quantitative interpretation of Bourdieu. In the cultural diffusion model developed by Axelrod (1997), probabilities of interaction between agents are based on the similarity of cultural traits. 'The basic premise is that the more similar an actor is to a neighbour, the more likely that that actor will adopt one of the neighbour's traits' (ibid, p. 203). This is a particularly suitable vehicle for modelling Bourdieu. First, Bourdieu also has a probabilistic approach to explaining how social structures can emerge from the behaviour of individual actors. Second, unlike most other agent-based models the Axelrod model is multi-dimensional, allowing more than one cultural feature to be modelled (see Axelrod 1997, p. 207). Bourdieu also sees the formation of social classes in a multi-dimensional social space, with different types of capital: economic, cultural and social, symbolic, etc. Third, as argued by Kennedy (1998, p. 58), the Axelrod model 'demonstrates that a small number of exceedingly simple principles can cause an artificial system to behave remarkably like a complex human society'. It will be demonstrated that the simplicity of Axelrod's approach is particularly useful for making operational the concept of habitus. Finally, a key characteristic of Bourdieu's approach is the grounding of theoretical concepts in empirical evidence, including quantitative survey data. Using correspondence analysis, a statistical technique pioneered in France and employed by Bourdieu, this paper will explore how results produced by the Axelrod model can be compared with survey data.

Section 2 will consider how Bourdieu's social theory can be related to the Axelrod model. In section 3, we report simulations of Bourdieu's theory in its most basic form, with the

introduction of capital effects. Section 4 turns to an analysis of Bourdieu's notion of distinction, comparing the output of our simulation model with an analysis of survey data. This draws from a major research project on cultural capital in contemporary Britain (Cultural Capital and Social Exclusion or CCSE) carried out by sociologists at the Centre for Research on Socio-Cultural Change (Bennett et al 2008). A summary of conclusions is provided in section 5.

## 2. Modelling Bourdieu's Social Theory

### The Axelrod Model

Axelrod's cultural diffusion model (Axelrod 1997) allows culture to have a number of different attributes or features. Associated with each artificial agent $i$ is a vector of $F$ cultural features $(\sigma_{i1}, \sigma_{i2}, ..., \sigma_{iF})$.[3] Each cultural feature $\sigma_{if}$ has a set of traits $\{1,...,q\}$. If, for instance, 'language' is the first cultural feature, then the language spoken - Arabic, French or German, for example - would be the particular cultural trait assigned to this feature. The focus is not, however, upon the content of these cultural features, but the role they play in the interaction that takes place between individuals.

Agents are arranged in sites in a square lattice. The probability of interaction between an agent $i$ and that agent's neighbour $j$ is proportional to the cultural similarity between two agents. If, for example, both agents speak French, they are more likely to interact, and imitate other cultural features. The cultural similarity $(l_{ij})$ between agents $i$ and $j$ is defined by the number of features which two agents have in common:

$$l_{ij} = \sum_{f=1}^{F} \delta_{\sigma_{if}, \sigma_{jf}}$$

where the difference function $\delta_{a,b} = 1$ if $a = b$ and $= 0$ if $a \neq b$.

Cultural diffusion takes place through the population of agents in a dynamic process structured by two steps:

**Step 1** An agent $i$ is chosen at random, together with a neighbour $j$.

**Step 2** The bond between two agents on neighbouring sites $(i, j)$ is active if $l_{ij} > 0$. An interaction consists of a feature $f$ that is not common between $i$ and $j$ (if any for $f = 1,...,F$) being randomly chosen, and agent $i$ with probability $l_{ij}/F$ adopting $j$'s trait for that cultural feature.

Axelrod's simulation of this model produces the somewhat surprising result that repeatedly running this process of interaction can reach an equilibrium which is not a monoculture. Separate cultural groups are formed, in which a cluster of contiguous agents have the same cultural features as other members of their group, but in equilibrium are completely different from members of neighbouring cultural groups.[4] Local convergence between agents leads to global polarization. Axelrod (1997, p. 212) found, with $F = 5$ and $q = 10$, there to be an average of 3 separate cultural groups (referred to as regions) in multiple runs of the simulation. Equilibrium is established when all neighbouring groups have no cultural features in common, preventing any further interaction between sites.

**Introducing Bourdieu**

Bourdieu's social theory also explores how separate cultural groups, more specifically social classes, are formed and reproduced. For Bourdieu there are species of capital that perform a similar role to Axelrod's notion of a cultural feature. Alongside economic capital, which represents individual holdings of money income and wealth, Bourdieu introduces the notion of 'cultural capital'; an individual's accumulated stock of knowledge about the products of artistic and intellectual traditions.[5] Cultural capital can be represented in concrete form by a multitude of variables, such as types of educational qualifications, or quantitative measures of cultural knowledge in different fields such as art and music. For Bourdieu (1984, p. 23), cultural capital is 'inscribed, as an objective demand, in membership of the bourgeoisie and in the qualifications giving access to its right and duties'. Together with economic capital, which provides a material starting point for Bourdieu's analysis, cultural capital has a constituent role in the structuring of social classes, and their reproduction over time.

Economic and cultural capital together provide two dimensions of a social space: 'It follows that all agents are located in this space in such a way that the closer they are to one another in those two dimensions, the more they have in common; and the more remote they are from one another, the less they have in common' (Bourdieu 1998, p. 6). In this social space, there is for Bourdieu (1990, p. 73) 'a practical mimesis', in which agents mimic the cultural and economic capital of other agents. This mimicry depends on the similarities between stocks of capital held by interacting agents: 'proximity in social space predisposes to closer relations: people who are inscribed in a restricted sector of the space will be both closer….and more disposed to get closer…' (Bourdieu 1998, p. 10).

This social space has a striking resemblance to Axelrod's multi-dimensional model, in which interaction is based on how closely agents are related in their cultural features. For Bourdieu, interaction is based on how closely agents are related in their holdings of capital. Moreover, Bourdieu (1984, p. 572) relates this social space to a geographical space in which culture is diffused through 'social contacts favoured by spatial proximity'. The geographical positions modelled in the Axelrod square lattice similarly ground cultural diffusion in social contacts between neighbouring spatial positions.

Bourdieu also views interaction in a probabilistic way, which makes it particularly suitable for agent-based modelling. Bourdieu (1993, p. 30) refers to a 'problematic' in which each agent has a probability of achieving a particular social position.[6] This probabilistic approach allows Bourdieu to address the age-old tension in sociology between structure and agency. Using the habitus, a framework in which cultural habits and practices are anchored in agents, individual actions are both structured and determining of structure in Bourdieu's analysis. 'The habitus is not only a structuring structure, which organizes practices and the perception of practices, but also a structured structure…' (Bourdieu, 1984, p. 170). First, by copying the capital structure of other individuals, the overall structural distribution of capital between individuals is determined by the actions of those individuals. Second, the initial distribution of capital between individuals provides a structural constraint on the extent to which individuals can engage in such copying. By ascribing probabilities to human action, Bourdieu ensures that social structure cannot completely dominate individual actions, and individual actions cannot completely drive structure.

Axelrod's probabilities of interaction, when interpreted in the light of Bourdieu's analysis, provide a simple way of capturing the relationship between capital structure and the actions of individuals. In Axelrod's multi-dimensional lattice, the probability of interaction depends on the degree of similarity between agents in terms of their cultural features. Once the analytical leap is made from Axelrod's cultural features to Bourdieu's species of capital, the Axelrod model provides a possible starting point for modelling Bourdieu's probabilistic insights.

**Extending the Axelrod Model**

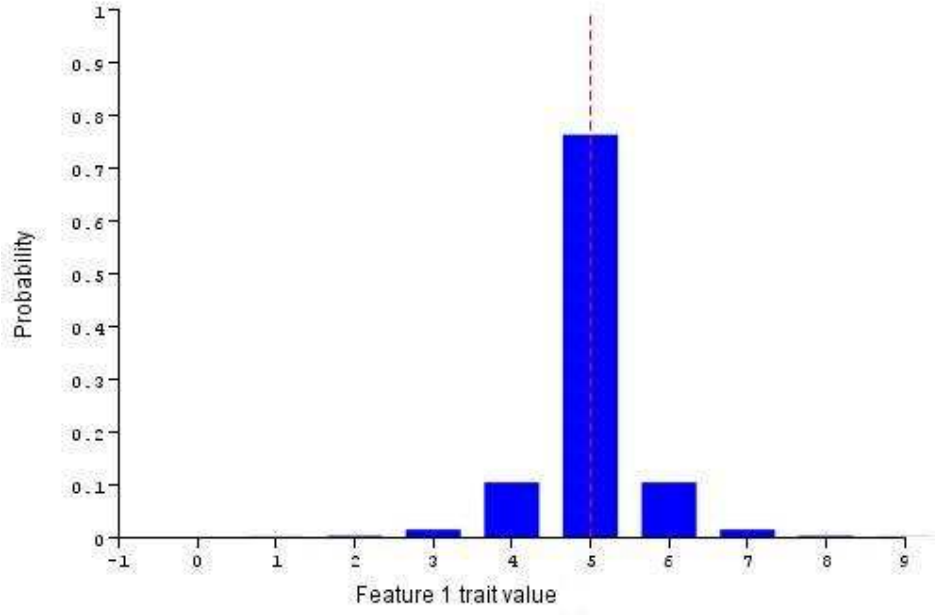
A key extension is required in order to model Bourdieu's notion of capital, since the Axelrod model does not ascribe any hierarchy to its cultural features. The traits are merely varying codes, as represented in the example of different languages. However, if we wish to reinterpret particular cultural features as forms of capital, then the trait values of those features must have a hierarchical structure. If cultural feature $f$ is defined as a form of capital, for example, then a trait value of 9 for feature $f$ denotes a higher value of that form of capital than a trait value of 5.

In this hierarchical way of thinking, the probability of interaction of two individuals depends on the difference in their levels of capital. In this, Bourdieu places particular importance on the role played by economic capital: 'economic capital is at the root of all the other types of capital' (Bourdieu 1986, p. 252). The level of economic capital enjoyed by each class fraction (a group of individuals with the same level of economic capital) has a strong influence on the interaction and social mobility that can take place between it and other class fractions. There is a dominant class fraction at the top of the hierarchy of economic capital: 'The probability of entering a given fraction of the dominant class from another class is….in inverse ratio to the position of that fraction in the hierarchy of economic capital' (Bourdieu, 1984, p. 132).

To make this insight operational, we introduce a constraint on interaction between individuals, based on their position in the hierarchy of economic capital. Following Bourdieu's approach, the probability of agent $i$ adopting the economic capital of agent $j$, and thus moving into $j's$ class fraction, will be constrained by the distance between those two class fractions - the difference in their levels of economic capital.

We model this by introducing the function $P = P(\sigma_{i1}, \sigma_{j1})$, where the first feature represents economic capital and $P$ gives the conditional probability that agent $i$ will adopt one of $j$'s features, conditional on an interaction taking place between the two agents according to the normal Axelrod interaction rules. To capture the effect of economic capital in reducing social mobility, $P$ is a decreasing function of economic distance, the difference between levels of economic capital, $\sigma_{i1}$ and $\sigma_{j1}$. Thus the greater the distance between levels of economic capital, the less likely an interaction will take place. Figure 1 displays the probability of interaction with individual $j$ when, for example, the economic capital of individual $i$ (feature 1) is set at 5.

***Figure 1 Capital Constrained Probabilities of Interaction***




The function $P$ can be used to modify Step 2 of the Axelrod model:

**Capital-modified Step 2**

The bond between two agents on neighbouring sites $(i, j)$ is active if $l_{ij} > 0$. An interaction consists of a feature $f$ that is not common between $i$ and $j$ (if any for $f = 1,...,F$) being randomly chosen, and agent $i$ adopting $j's$ trait for that cultural feature with probability $P\ l_{ij} / F$, where $P = P(\sigma_{i1}, \sigma_{j1})$.

In this modification, the probability of interaction between agents in the Axelrod mechanism is constrained by their difference in economic capital. The simplicity of the Axelrod mechanism remains intact, with no means of interaction between individuals other than the adoption of neighbour's features, and the probability of interaction reflecting the number of similar cultural features (including economic capital). However, as a way of modelling the predominance of economic capital in Bourdieu's approach, this probability of interaction mechanism is modified to give particular weight to the difference in levels of economic capital.

## 3. Simulating Capital

The Repast agent modelling system (North et al. 2006) has been used to replicate the Axelrod model and introduce the capital modification suggested by Bourdieu's social theory. The starting point is the Axelrod (1997) simulation in which there are 5 cultural features, with 10

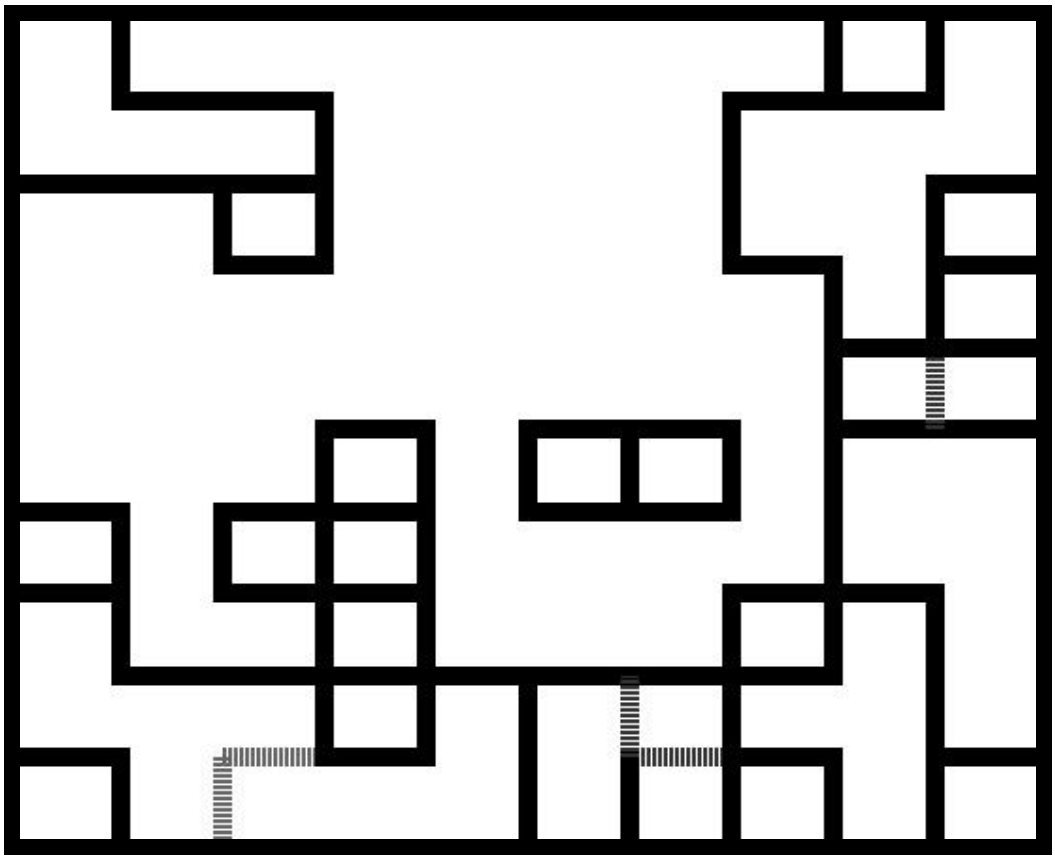
traits per feature, and each active site interacts with close neighbours in the lattice, to the north, east, south and west. The capital constraint, as shown in the capital-modified Step 2, is applied to the first feature, which is assumed to represent economic capital.

Figure 2(a) shows a typical quasi equilibrium position produced by the capital-modified Axelrod model. A position of quasi equilibrium is established once there are no changes in the number of cultural groups between 1,000 runs of the simulation. This contrasts with the complete equilibrium produced by the Axelrod model, in which no further change can happen.

Clustering of agents is illustrated by the shading of straight lines in Figure 2(a), which indicate the degree of cultural similarity between agents. Solid black lines are drawn between agents that have no features sharing the same traits. No lines are drawn between clusters of agents that have all features sharing the same traits (i.e. identical cultures). Otherwise broken grey lines are drawn, the degree of greyness proportional to the cultural similarity of the agents.

***Figure 2 Typical Final Outcome for the Capital-Modified Axelrod Model***

*a) Line Display*



*b) Cell Matrix*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22655 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 35786 | 09928 |
| 22655 | 22655 | 22655 | 50510 | 50510 | 50510 | 50510 | 09928 | 09928 | 09928 |
| 50510 | 50510 | 04891 | 50510 | 50510 | 50510 | 50510 | 09928 | 09928 | 71257 |
| 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 09928 | 40660 |
| 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 50510 | 18051 | 98385 |
| 50510 | 50510 | 50510 | 06076 | 50510 | 98472 | 74259 | 50510 | 77204 | 77204 |
| 05367 | 50510 | 25365 | 84894 | 50510 | 50510 | 50510 | 50510 | 77204 | 77204 |
| 98834 | 50510 | 50510 | 02452 | 50510 | 50510 | 50510 | 19381 | 64763 | 77204 |
| 98834 | 98834 | 98834 | 25706 | 01234 | 66353 | 06937 | 64763 | 64763 | 77204 |
| 44659 | 98834 | 01234 | 01234 | 01234 | 66353 | 99739 | 48577 | 64763 | 90050 |

Axelrod refers to a group of agents with no lines drawn between them as *cultural regions*: 'contiguous sites with an identical culture' (Axelrod, 1997, p. 211). Consider the trait values associated with the region in the top left of Figure 2(a). Adjoining sites in this region have identical values (2, 2, 6, 5, 5), as shown in Figure 2(b).

Figure 2(a) produces more cultural regions than the Axelrod model, 28 compared to 3 regions produced by the typical Axelrod model. The capital constraint in this run of the simulation generates a more multicultural outcome. Furthermore, in Figure 2 there are *cultural zones*, where contiguous sites have at least one cultural feature in common. Each region is by definition a zone, but in Figure 2 there are also 3 zones that are not regions (not all cultural features are identical). In contrast to the basic Axelrod model, interaction between agents over a long time does not eradicate all the cultural zones. Since these zones exist in a quasi equilibrium, the probability of interaction between agents is small but not zero.[7]

This can be explained by examining the trait values in Figure 2(b). Consider the two underlined sites (1, 8, 0, 5, 1) and (9, 8, 3, 8, 5). These sites taken together represent a cultural zone since the second cultural feature is the same (at 8) between the two neighbours. But note that the values of economic capital, the first element, are very different (at 1 and 9). In the Axelrod model, one would expect these sites to eventually interact, because there is some similarity. However, in the capital-modified model the chances of interaction are remote (but not zero) because of the marked disparity in economic capitals.

**Results**

Our simulation of the Axelrod model over 200 runs, with 5 cultural features and 10 traits, produces a median of 3 zones, which reproduces Axelrod's result. In contrast, for the capital-modified model an equivalent outcome of 26 zones is produced. With the Bourdieu extension, the simulation produces a significantly more multicultural outcome than the original Axelrod model.

This latter result is reported in Table 1, together with additional results obtained from varying the number of features and traits. Compared to the same exploration carried out by Axelrod (1987, p. 212) for his unconstrained model, this further confirms the finding that the capital-constrained model leads to a more multicultural outcome. For the combination of 5 features and 15 traits, for example, a median of 47 zones is reported over 200 runs, compared to 20 in the original Axelrod simulation. It should also be noted that Table 1 confirms the Axelrod result that increasing the number of features leads to a less multicultural outcome. At 10 cultural traits, for example, the median number of zones falls to 2 when there are 15 features, compared to 26 for 5 features.

***Table 1 Median Number of Zones for Capital-Constrained Model***

| *No. of cultural features* | *Traits per feature* | | |
|---|---|---|---|
| | 5 | 10 | 15 |
| 5 | 3 | 26 | 47 |
| 10 | 1 | 5 | 17 |
| 15 | 1 | 2 | 6 |

(200 runs)

The impact of the capital constraint can be further examined using the Gini coefficient: a ratio with values between 0 and 1, where 0 corresponds to perfect equality and 1 to perfect inequality. Applied to the first feature, it is considered as a summary measure of the degree of economic inequality between holdings of economic capital in the extended Axelrod model. Table 2 reports values of the Gini coefficient when the number of traits and features are varied. The model with 5 features and 10 traits produces a Gini of 0.3656, which is within the range of Gini coefficients reported for Western economies.[8] This shows that the capital constraint for one feature (economic capital) is sufficient for the reproduction of considerable inequality in a modified Axelrod model; this is not dissimilar from the average Gini coefficient of 0.3645 of the initial lattice before the simulation is started.

***Table 2 Mean Gini Coefficients for Capital-Constrained Model***

| *No. of cultural features* | *Traits per feature* | | |
|---|---|---|---|
| | 5 | 10 | 15 |
| 5 | 0.4369 | 0.3656 | 0.3501 |
| 10 | 0.4694 | 0.3635 | 0.3560 |
| 15 | 0.4721 | 0.3636 | 0.3520 |

(200 runs)

Moreover, the Gini coefficient is quite robust to changes in the parameter space, varying from 0.3501 to 0.4721 (see Table 2). Mean Gini coefficients of 0.4694 and 0.4721 are produced even when, as shown in Table 2, the number of zones is reduced to 1 (for combinations of 10 or 15 features with 5 traits). For such outcomes most cultural features are the same apart from differences in economic capital. This further demonstrates how well economic inequality is reproduced by the capital modification to the Axelrod model.

These results offer some clarity on the role of capital in Bourdieu's system. As Gilbert and Troitzsch (1999, p. 5) argue, simulations of this type can involve 'being precise about what the theory means and making sure that it is complete and coherent, a valuable discipline in its own right'. By adapting the Axelrod simulation approach, a precise and coherent theoretical model of inequality is established for the economy as a whole (the economic field) with only one species of capital. A baseline model of Bourdieu, with the minimum requirements (one capital feature) is sufficient for establishing the emergence of economic inequality. This theory is complete, at this basic level of abstraction, without requiring Bourdieu's insights into the importance of other drivers of inequality such as cultural capital.

This theoretical insight could be potentially extended to other fields, in which different types of capital may be dominant. In the field of education, for example, Bourdieu argues that cultural capital has a key role. There is inequality in the chances of educational success because of the unequal distribution of cultural capital between individuals. Bourdieu's

argument has been challenged by Goldthorpe (1996), who argues that economic inequality is the main driver of inequality in educational outcomes. Others, such as Barone (2006), have given a more equal weighting to the importance of both economic and cultural capital. Our contribution, in formalizing Bourdieu, is to show that under certain simplified assumptions just one species of capital may be sufficient to model inequality. This could be either cultural or economic capital, depending on the field or context, but the need for a multi-capital framework to explain inequality is brought into question by this finding.

It should also be emphasised that the baseline capital model, as we have applied it to the economic field, generates economic inequality in a very specific multicultural context. Although it produces a variety of configurations of cultural features, these features do not represent capital, since there is no hierarchy ascribed to their values. Further theoretical precision is offered by distinguishing between segments and hierarchies (see Anheier, Gerhards and Romo 1995). Culture is segmented when there are a 'number of relatively distinct, structurally separate, and unrelated parallel components of the social structure' (ibid, p. 865) For there to be a hierarchy between two segments, however, there must be status differences under which one of them is be defined as elite, the other as being in some sense peripheral. In the next part of the paper, we look in more depth at how Bourdieu models cultural differences in status.

## 4. Distinction

An important concept developed by Bourdieu is his notion of distinction, under which agents with high levels of economic capital engage in cultural innovation. This is achieved by those at the top of a social hierarchy developing 'strategies for outflanking, overtaking and display' (Bourdieu 1984, p. 282), which set their cultural tastes apart from others. New cultural products are developed and consumed in 'a permanent revolution in tastes' (ibid, p. 282). A cycle of innovation takes place in which new cultural forms are continuously introduced by those at the top of the social hierarchy, to be subsequently copied by others lower down the hierarchy.

Since many people find it difficult to copy (high status) innovative cultural tastes, the latter are interpreted by Bourdieu as displaying the characteristics of capital: scarce and difficult to acquire. More precisely, these tastes can be defined as cultural capital. By engaging in distinction, high status individuals can develop cultural capital which restricts the possibility of lower status individuals moving up the social hierarchy. Alongside our previous hierarchy in economic capital (the first cultural feature), a hierarchical notion of cultural capital is now introduced, by which a number of cultural features can represent differences in status.

### Simulating Distinction

In order to introduce distinction into our model of Bourdieu, the first of Axelrod's cultural features is again defined as economic capital. The probability of innovation can then be made proportional to economic capital. The richer the individual, the more likely they are to innovate – enabling them, for example, to pay for theatre tickets, purchase paintings, travel abroad: activities that allow them to pursue and develop new cultural tastes. Innovation here takes the form of new traits that are added to existing cultural features. Axlerod (1997, p. 221) refers to this type of innovation as 'technological change (continuing introduction of new and more attractive traits)'. Cultural capital, rooted in this innovation process, is hence modelled in a way that is different from how economic capital was modelled. Whereas in Section 3 economic capital was modelled by making the first cultural feature hierarchical, cultural capital makes a number of remaining cultural features hierarchical. However, the particular importance given to economic capital remains.

A new innovation event (Step 3) can be defined. The proportional relationship between innovation and economic capital is captured by the probability function $\mu(\sigma_{i1})$, which gives the probability of agent $i$ introducing an innovation event, where $\sigma_{i1}$ is agent $i's$ economic capital. Once an innovation event takes place, then one of $i$ 's other cultural features is randomly chosen, for $f > 1$ , and the value of that cultural feature is changed to a new trait value, which has a value outside of the $\{1,...,q\}$ existing set of traits. In addition, we define a maximum value $m$ of the number of possible innovation trait values.

## Step 3

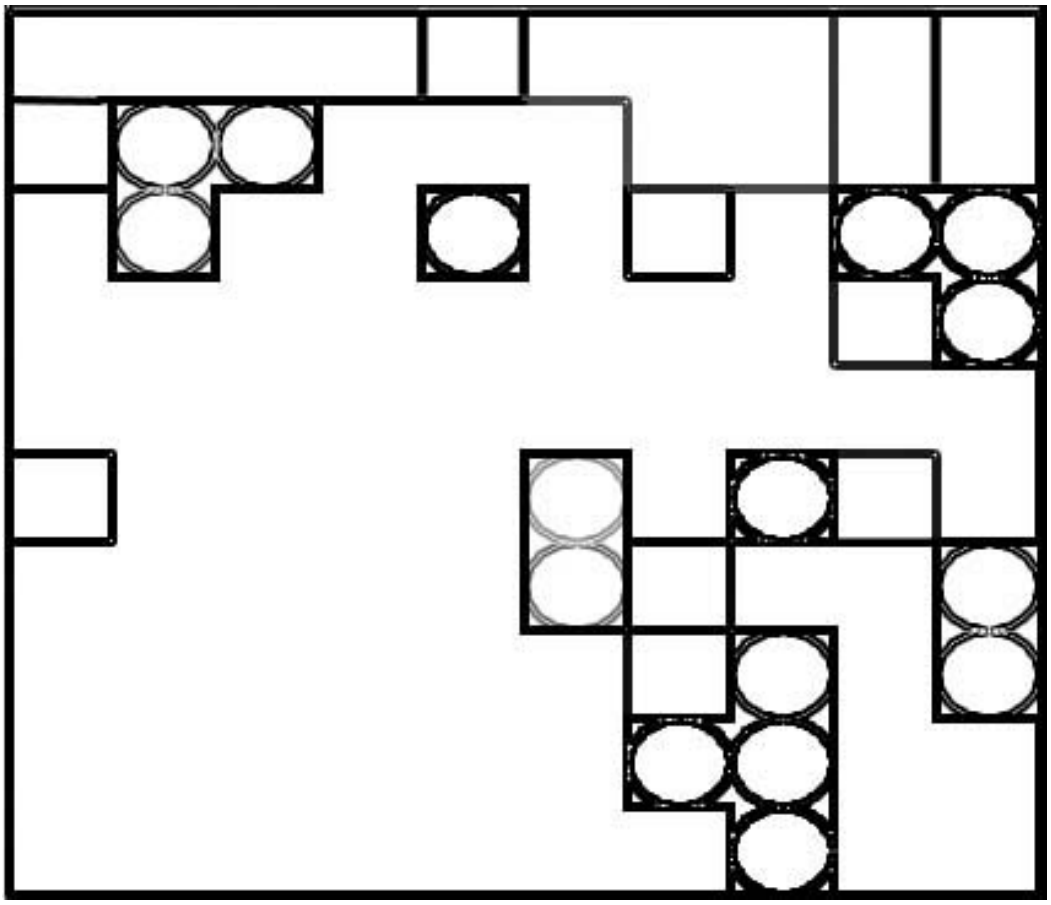
A site $i$ is chosen at random, and with probability $\mu(\sigma_{i1})$ an innovation event occurs as follows: (a) one of $i$ 's features is chosen at random from the set of eligible features $\sigma_{if}$, $f > 1$ ; (b) the trait value of the chosen feature $\sigma_{if}$ is changed to a random integer from the set of trait values $\{q+1,...,m\}$.

This approach is rather simplified, given the complexities of Bourdieu's notions of distinction and the structure of capital. Gartman (2002), for example, has emphasized the important role in Bourdieu's system played by different fractions of the dominant class. Innovations in culture are sponsored and legitimized by those with high economic capital, but can originate in more intellectual (high cultural capital) fractions of the dominant class. A simplified approach is taken here in order to develop an agent-based model that is easy to understand as a starting point for modelling Bourdieu.

Figure 3 shows a typical final outcome (in this case with complete convergence) of the capital-modified Axelrod model extended by the new innovation mechanism introduced in Step 3.[9] In part (a), agents that have introduced new traits are represented by circles, the remaining agents being those that have not engaged in innovation. Compare the two underlined sites (0, 1, 0, 3, 2) and (9, 26, 20, 29, 37) in part (b). The first agent has an economic capital (the first feature) of 0 and has not engaged in innovation – all of its traits are between 0 and 9. In contrast, the second agent has a high economic capital of 9, and has introduced new traits of 26, 20, 29 and 37. This illustrates how step 3 works, with innovation events more likely to happen for agents with high economic capital.

***Figure 3 Typical Final Outcome: Innovation and Capital-Modified Axelrod Model***

*a) Line Display*



*b) Cell Matrix*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 4 7 2 1 | 1 4 7 2 1 | 1 4 7 2 1 | 1 4 7 2 1 | 5 8 1 6 4 | 1 4 3 1 2 | 1 4 3 1 2 | 1 4 3 1 2 | 5 9 0 8 0 | 2 6 6 3 5 |
| 2 8 2 8 8 | 9 2 4 30 21 38 | 9 2 4 30 21 38 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 1 4 3 1 2 | 1 4 3 1 2 | 5 9 0 8 0 | 2 6 6 3 5 |
| 0 0 0 0 0 | 9 2 4 30 21 38 | 0 0 0 0 0 | 0 0 0 0 0 | 9 44 41 34 29 | 0 0 0 0 0 | 3 9 8 2 5 | 0 0 0 0 0 | 8 7 15 13 19 | 8 7 15 13 19 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 5 2 3 2 2 | 8 7 15 13 19 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 |
| 1 6 9 6 7 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 9 29 34 24 24 | 0 0 0 0 0 | 7 11 11 2 3 | 1 8 1 4 8 | 0 0 0 0 0 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 9 29 34 24 24 | 2 2 4 9 1 | 0 1 0 3 2 | 0 1 0 3 2 | 9 26 20 29 37 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 1 8 2 2 9 | 9 40 37 30 28 | 0 1 0 3 2 | 9 26 20 29 37 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 9 40 37 30 28 | 9 40 37 30 28 | 0 1 0 3 2 | 0 1 0 3 2 |
| 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 0 0 0 0 0 | 9 40 37 30 28 | 0 1 0 3 2 | 0 1 0 3 2 |

An exploration can now be carried out of the parameter space associated with the innovation extension to the capital-modified Axelrod model (with 5 cultural features and 10 traits per feature). Restrictions can be placed on the number of features that are eligible for innovation – referred to here as innovation features. If there are 3 innovation features, for example, this means that only 3 of the features are eligible for innovation. The first row of Table 3 shows the median number of zones produced by 200 runs for each number of innovation features. As the number of innovation features is introduced, from 0 to 4, there is a slight increase in the number of zones, from 26 to 34; but this increase does not radically change the multicultural outcome of the capital-modified model. Similarly, the addition of more innovation features

has no significant impact on the size of the Gini coefficient: 0.3656 for 0 innovation features, 0.3645 for 1 innovation feature, and a very similar 0.3650 for 4 innovation features. A Gini coefficient of around 0.36 is established, regardless of the number of features for which innovation is modelled. Innovation effects have no consistent impact on the reproduction of economic inequality in the extended Axelrod model.

***Table 3 Innovation and the Capital Modified Model***

| | ***Number of innovation features*** | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| **Median no. of zones** | 26 | 28 | 30 | 32 | 34 |
| **Mean Gini Coefficient** | 0.3656 | 0.3645 | 0.3665 | 0.3630 | 0.3650 |

(200 runs)

This is a quite surprising result given the importance that has been placed on Bourdieu's concept of distinction, and its impact on inequality. Moreover, it necessitates a deeper exploration of the role played by distinction and cultural capital in the Bourdieu system. Although we have found that our modelling of distinction does not have a significant impact on the reproduction of economic inequality, it may still have an important role to play in understanding structural patterns of cultural capital; how it is distributed between individuals. To explore the role of distinction further, we now turn to a consideration of how the Bourdieu model can be compared with a recently produced survey of cultural practices in the U.K.

**Correspondence Analysis**

An important dimension to Bourdieu's analysis of cultural capital is the way in which it is grounded in empirical observation. Most notably, he carried out a questionnaire survey of cultural practices and competencies in France during the early 1960s (Bourdieu 1984). With this data, Bourdieu championed correspondence analysis, which has been used mainly by French social scientists (see Benzecri 1992), and more recently in the Cultural Capital and Social Exclusion (CCSE) project (see Gayo-Cal et al 2006). Correspondence analysis is a descriptive technique that explores structural patterns in data, visualized using geometric diagrams.

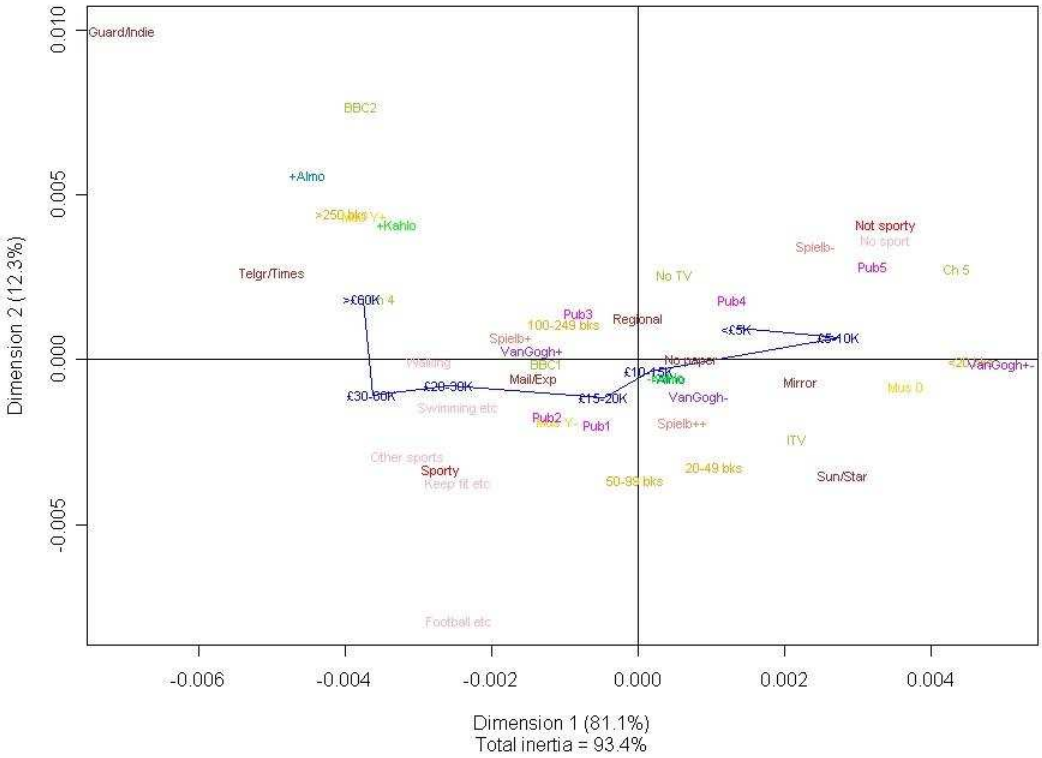
In order to develop the role of cultural capital in our model of Bourdieu, we compare findings from CCSE data with output from the extended Axelrod model. The correspondence analysis reported here uses different variables to those used by the CCSE researchers in constructing their 'space of lifestyles' and therefore offers valuable comparison with their results (see Bennett et al 2008). The data is based on a 2004 sample of representative adults living in the U.K. Just over 1,500 respondents were asked questions designed to explore their cultural capital – for example, visits to museums, number of books in the house, and activities such as sport or newspapers purchased. Variables used here are reported in the Appendix.

The objective of multiple correspondence analysis (see Greenacre and Blasius 1994) is to explain total inertia (chi-squared/N) with a small number of joint plots. The axes of each plot are referred to in correspondence analysis as dimensions. This can be thought of as the extension of principal component analysis to categorical data. The dimensions produced by correspondence analysis are equivalent to the underlying factors produced by principal component analysis.

Figure 4 reports a joint plot for the first of these two dimensions - the two best available dimensions to bring out the structure in the data. Note that there is no preconceived assumption about what these dimensions represent; this comes out of how the data is interpreted.

Each point on Figure 4 represents one category of a variable. For example, the variable representing which newspapers individuals read has categories Telgr/Times (*The Daily Telegraph* or *The Times* broadsheets) in the top left of Figure 4, and Sun/Star (tabloids *The Sun* or *Daily Star*) in the bottom right.

***Figure 4 Joint Plot of Cultural Survey***




The relative positions of points in Figure 4 offer insights into associations between variables that may exist in the data. In the top left quadrant, for example, there is a close association between points representing the reading of broadsheet newspapers (Telgr/Times), possessing more than 250 books (>250bks), and watching the television channel BBC2. Also forming part of this cluster are points indicating knowledge of the Spanish film director Almodovar (+Almo) and the Mexican artist Frida Kahlo (+Kahlo). The close distance between these data points suggests a clustering of high cultural capital. Reading an established broadsheet newspaper like the *The Times* could be interpreted as legitimate tastes; but a knowledge of the avant-garde Spanish film director Almodovar suggests a more innovative profile (see Hill (2004) for examination of the relationship between film and cultural capital). Bennett et al (2005) also associate admiring the works of Frida Kahlo with the 'greatest taste risk takers, suggesting an *avant-garde* rather than a legitimate taste formation.' The possession of books

and watching BBC2, a somewhat highbrow public service channel in the U.K., may be associated with both innovative and legitimate tastes.

This cluster of high cultural capital is also associated with high income, with the data point representing the highest level of income (>60k) located in close proximity. Following Bourdieu (1984), we can interpret the income variable as representing economic capital. Hence, the cluster in the top left quadrant of Figure 4 can be interpreted as representing high cultural and economic capital at the top of the social hierarchy.

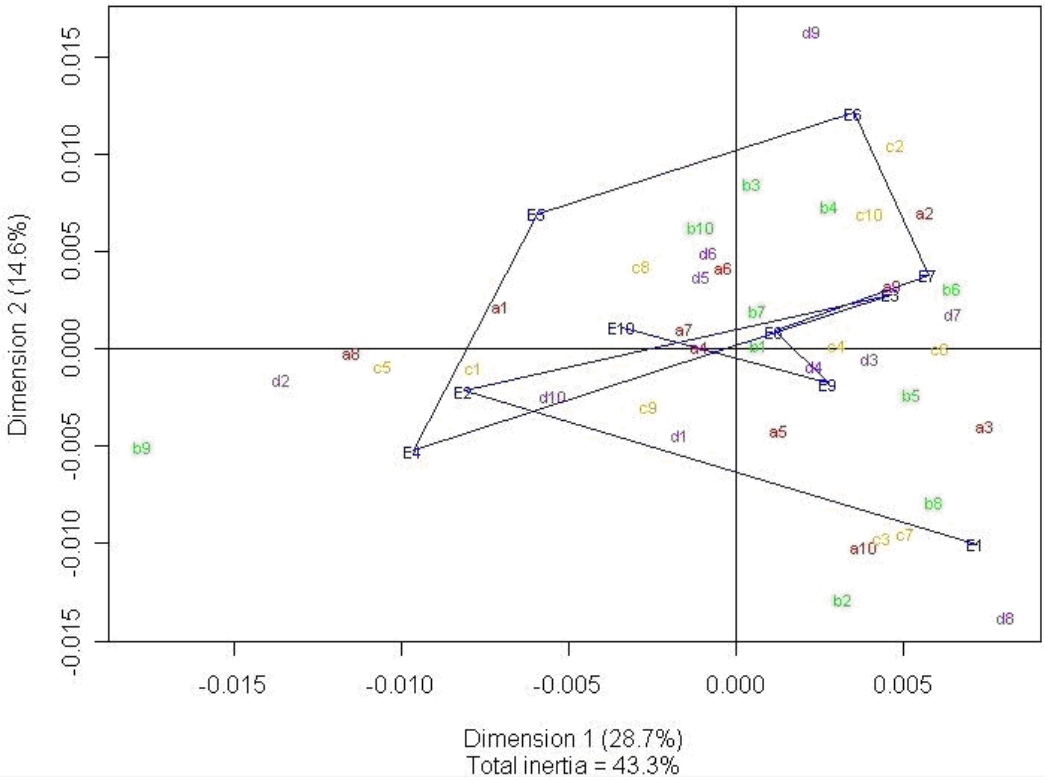
From Bourdieu's perspective, this type of association between variables is evidence of there being a habitus for the dominant social class. High income, knowledge of avant-garde culture, reading of books and broadsheet newspapers: these attributes characterise the lifestyles of members of the dominant class. For Bourdieu this is seen as a structural constraint – a set of practices which membership of the dominant class tends to require. As we have seen, this structural constraint is, however, not completely determinant because of the probabilistic nature of Bourdieu's system.

Points representing different levels of economic capital are joined up using the line displayed in Figure 4. The horizontal trajectory of this line suggests an interpretation of the horizontal axis (dimension 1) as capturing economic capital. Moving right to left on Figure 4, low levels of economic capital such as £5-10K build up to the highest level of economic capital (>60k) at the far left. Low levels of economic capital are associated with low levels of cultural capital - reading tabloid newspapers (Mirror), not visiting museums (Mus0) and watching the largest commercial/popular channel in the U.K (ITV). [10] Following Bourdieu's approach, this cluster can be interpreted as evidence of a dominated class habitus.

Correspondence analysis lends itself to a comparison of survey results with the output of simulations. Using correspondence analysis, it is not necessary to have either the same number of variables as in the simulation or as many agents in the simulation as respondents in the survey. This enables to us compare the survey results with pooled results from 10 simulations of the extended Axelrod model. Equilibrium outcomes of the Axelrod model are pooled together to make 10 sets of data points. As before, this model of Bourdieu has five features, with new innovative traits added to the initial set of 10 traits.

Figure 5 shows a joint plot produced by ten simulations of the most basic version of the extended Axelrod model, with economic capital but no innovation effects. Correspondence analysis is carried out for all five features, including the first feature representing economic capital (E) and the other four cultural features (a, b, c, and d). The cultural feature 'a', for example, has category points 'a1', 'a2', etc., and the economic capital variable has points 'E1', 'E2', etc.

***Figure 5 Joint Plot of Simulation: Zero Innovation Features***

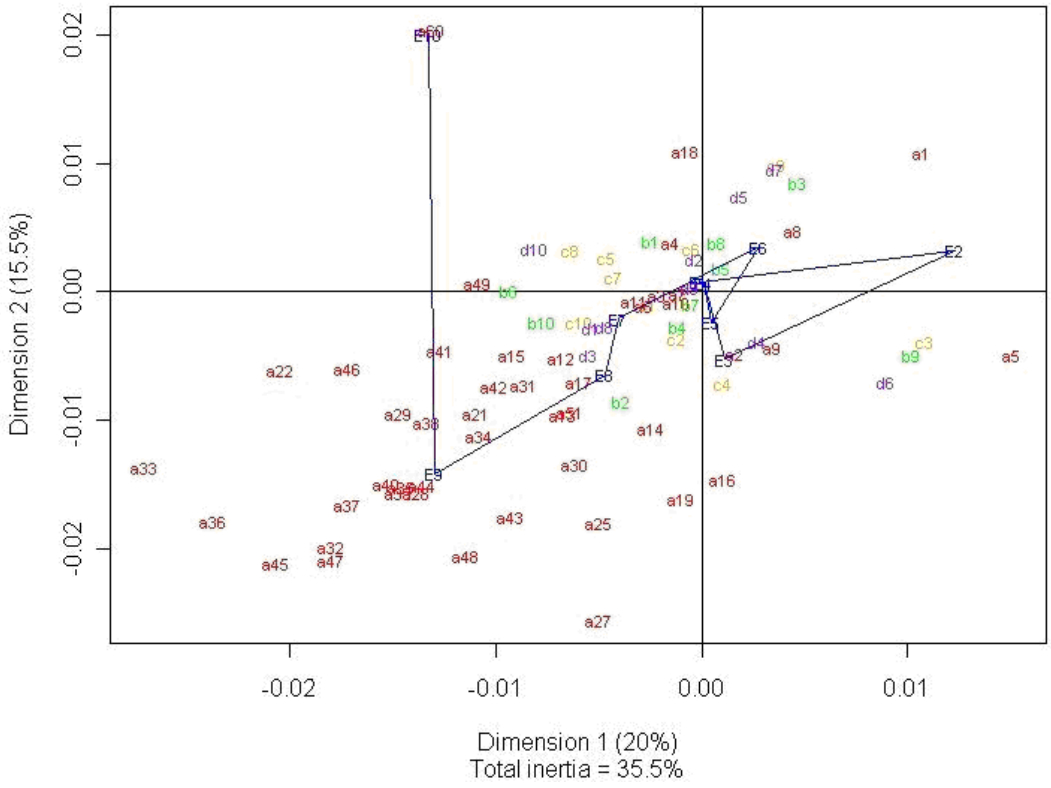



(10 runs)

No particular structure can be discerned for Figure 5, either in the pattern of economic capital or the other cultural features. The category point representing the highest level of economic capital (E10) has no obvious cluster of cultural features associated with it. Furthermore, the economic capital variable is not associated with any of the two axes in the diagram. The capital modification to the Axelrod model does not produce a structural outcome that is comparable with the survey data.

In Figure 6, on the other hand, structural patterns are beginning to be revealed that are quite consistent with the survey data. Here one cultural feature (feature a) is now modified to include innovation, with innovative cultural traits new to the original trait values a1 to a10. In the bottom left quadrant, E9 (the second highest level of economic capital) is in close proximity to innovative traits such as a37, a48 and a34. In contrast, the right hand side of Figure 6 reveals low levels of economic capital (E2 and E3) associated with no innovation: original values a9, a8 and a5. Figure 6 shows that moving from right to left, the path of the economic capital variable tends to follow the direction of the horizontal axis. Applying the innovation modification to the Axelrod model has enabled some reproduction of the structural patterns found in the survey data.

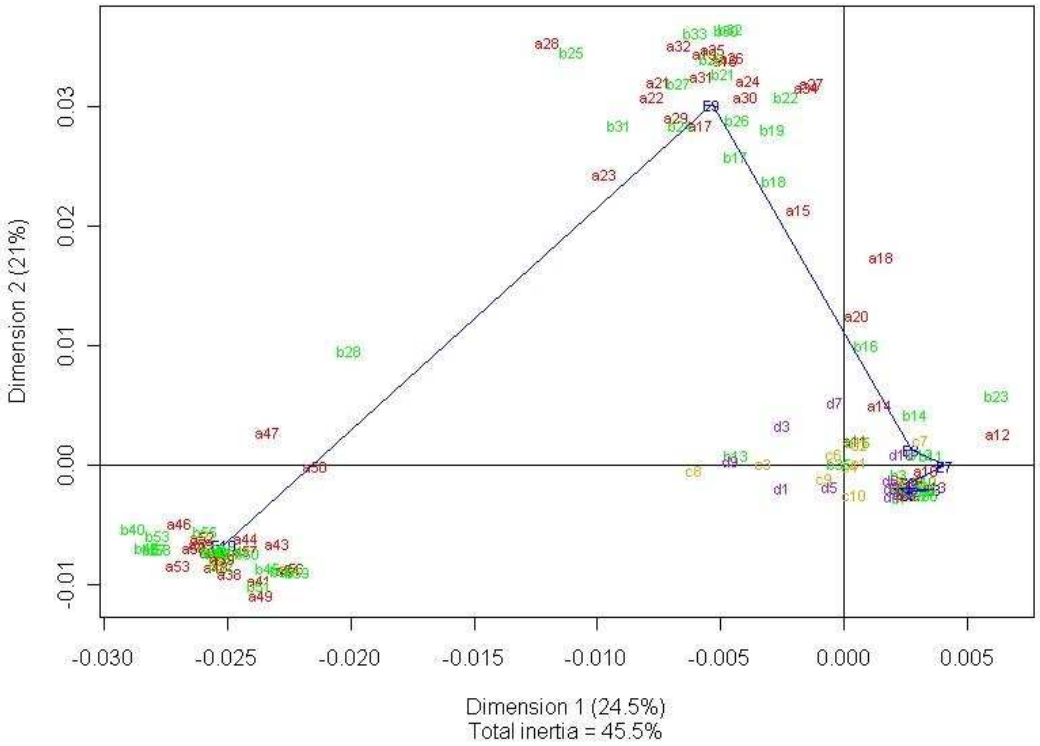
***Figure 6 Joint Plot of Simulation: One Innovation Feature***




(10 runs)

Applying the innovation modification to additional cultural features makes the clustering of innovative traits more pronounced. Figure 7 shows the results of pooled correspondence analysis for the capital-modified model with two innovation-modified features. We can see here the clustering of innovative trait values such as a44 and b53 around E10, the highest value of economic capital, and a distinct cluster of innovative data points around E9, the second highest value. Moreover, whilst E9 and E10 are on the left hand side of Figure 7, on the right hand side lower levels of economic capital are clustered together. The horizontal trajectory of economic capital is reproduced, but with the lower levels of economic capital clustered more closely together.

***Figure 7 Joint Plot of Simulation: Two Innovation Features***




(10 runs)

It can therefore be concluded that although distinction, as modelled by innovation effects, does not have a major role to play in modelling economic inequality in our Bourdieu framework, it can have a strong role to play in explaining structural patterns in cultural capital. Introducing innovation to the Axelrod model can model the habitus, helping to explain the association of particular clusters of cultural traits (cultural capital) with polar extremes in economic capital. On this interpretation, inequality in economic capital is associated with attendant inequalities in cultural capital. Inequality is not just economic; it pervades the cultural makeup of individuals, enhancing their cultural differences. Although the solution to tempering such inequalities may rest more with economic than cultural capital, our model of Bourdieu's system provides a way of exploring how these two forms of capital are intimately related.

## 5. Conclusions

Axelrod's cultural diffusion model provides a useful starting point for modelling Bourdieu's theories. Its multi-dimensional structure provides a way of quantifying Bourdieu's multi-capital theory, making it accessible to an economics and quantitative sociology audience. Concepts with which the economic literature has not engaged, such as habitus and cultural capital, can be modelled under very simple assumptions.

This paper gives some insight into the degree of theoretical complexity that is required for Bourdieu's social theory. Our specific contribution has been to decompose Bourdieu's theory

into two dimensions: capital and innovation effects. First, capital effects are modelled with the degree of interaction between individual agents restricted by their position in the economic hierarchy. Second, Bourdieu's concept of distinction is modelled by making cultural innovation proportional to economic capital. The capital effect is found to have a powerful impact, firmly establishing a multicultural equilibrium in which economic inequality is reproduced. Moreover, the capital constrained version provides a minimal baseline model for the reproduction of inequality, precluding the need for the capital effect to be extended to more than one cultural feature. On the basis of very simple assumptions, the need for a multi-capital framework for modelling inequality is brought into question.

Furthermore, distinction, modelled as an innovation effect, does not enhance the degree of economic inequality produced by repeated simulations. Its relevance is in explaining structural patterns in culture. Using correspondence analysis, innovation events are shown to generate clusters of culture capital (habitus) that are associated with high levels of economic capital; a structural pattern that is consistent with data points generated from a U.K. survey of cultural capital.

Our decomposition of Bourdieu's theory therefore points to the particular relevance of each of its two main dimensions – capital and innovation effects - to the understanding of economic inequality and the structural distribution of cultural capital respectively. This very abstract framework can in principle can applied to many different fields, as Bourdieu demonstrates in his own voluminous writings; including school and higher education, housing and art. In exploring the structure of agents' lifestyles, this framework also provides a possible vehicle for analysing the determinants of consumer behaviour. Our motivation is to provide a starting point for showing how Bourdieu's approach can be further developed with the enhanced clarity and theoretical precision offered by agent-based modelling.

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[1] Bourdieu was also described by Shusterman (1999, 1) as 'France's leading living social theorist'.

[2] By contrast, the related concept of social capital, which Bourdieu employs, has gained wide recognition (see Becker 1996).

[3] This formalization of the Axelrod model derives from Klemm et al (2005).

[4] The probability of choosing a neighbour that has completely different cultural features is zero in the Axelrod model. Durrett and Levin (2005) relax this assumption, providing possible pointers to other agent based modelling frameworks that could be used to model Bourdieu.

[5] This is a very simplified definition of cultural capital, which has different dimensions in Bourdieu's writings. In Bourdieu (1986, p. 243), for example, cultural capital has three different forms: embodied (related to the mind and body), objectified (taking the form of cultural goods), and institutionalized (educational qualifications).

[6] Bourdieu (1985, p. 724) uses a gambling metaphor to explain his probabilistic approach: 'The kinds of capital, like the aces in a game of cards, are powers that define the chances of profit in a given field'

[7] If complete convergence to equilibrium is not established after 100,000 runs, a position of quasi equilibrium is established once there are no changes in the number of regions and zones between 1,000 runs of the simulation.

[8] We know from cross-country comparisons that the Gini coefficient is between 0.25 and 0.4 in most Western economies. In the U.K. the Gini was 0.345 in 1999; for the US it was 0.368 and for France 0.278 in 2000 (Luxemburg Income Survey 2000).

[9] New traits are introduced under Step 3 up to a maximum trait value of $m = 50$.

[10] It should be noted that this correspondence analysis is different in two main ways from the original outputs produced by Bourdieu (1984). First, in order to simplify the comparison with the modified Axelrod simulation, we do not follow Bourdieu in treating economic capital as a supplementary variable to the correspondence analysis. Second, in his analysis of French cultural data in the early 1960s, Bourdieu associated cultural and economic capital with different dimensions of his joint plot. Our results associate these two types of capital with only one dimension. Such differences might be not be surprising given the contrasting cultures of France and Britain at different points in time

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