An Agent-Based Approach to Value Theory and Wealth Distribution in Economics

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EXTENDED ABSTRACT

Any attempt to model an economy requires foundational assumptions about the relations between prices, values and the distribution of wealth. These assumptions exert a profound influence over the results of any model. Unfortunately, there are few areas in economics as vexed as the theory of value. I argue in this paper that the fundamental problem with past theories of value is that it is simply not possible to model the determination of value, the formation of prices and the distribution of income in a real economy with analytic mathematical models. All such attempts leave out crucial processes or make unrealistic assumptions which significantly affect the results.

There have been two primary approaches to the theory of value. The first, associated with classical economists such as Ricardo and Marx were *substance* theories of value, which view value as a substance inherent in an object and which is conserved in exchange. For Marxists, the value of a commodity derives solely from the value of the labour power used to produce it - and therefore any profit is due to the exploitation of the workers. The labour theory of value has been discredited because of its assumption that labour was the only 'factor' that contributed to the creation of value, and because of its fundamentally circular argument. Neoclassical theorists argued that price was identical with value and was determined purely by the interaction of supply and demand. Value then, was completely *subjective*. Returns to labour (wages) and capital (profits) were determined solely by their marginal contribution to production, so that each factor received its just reward by definition. Problems with the neoclassical approach include assumptions concerning representative agents, perfect competition, perfect and costless information and contract enforcement, complete markets for credit and risk, aggregate production functions and infinite, smooth substitution between factors, distribution according to marginal products, firms always on the production possibility frontier and firms' pricing decisions, ignoring money and credit, and perfectly rational agents with infinite computational capacity. Two critical areas include firstly, the underappreciated Sonnenschein-Mantel-Debreu results which showed that the foundational assumptions of the Walrasian general-equilibrium model imply arbitrary excess demand functions and therefore arbitrary equilibrium price sets. Secondly, in real economies, there is no equilibrium, only continuous change. Equilibrium is never reached because of constant changes in preferences and tastes; technological and organisational innovations; discoveries of new resources and new markets; inaccurate and evolving expectations of businesses, consumers, governments and speculators; changing demand for credit; the entry and exit of firms; the birth, learning, and death of citizens; changes in laws and government policies; imperfect information; generalized increasing returns to scale; random acts of impulse; weather and climate events; changes in disease patterns, and so on.

The problem is *not* the use of mathematical modelling, but the *kind* of mathematical modelling used. Agent-based models (ABMs), object-oriented programming and greatly increased computer power however, are opening up a new frontier. Here a dynamic bargaining ABM is outlined as a basis for an alternative theory of value. A large but finite number of heterogeneous commodities and agents with differing degrees of market power are set in a spatial network. Returns to buyers and sellers are decided at each step in the value chain, and in each factor market, through the process of bargaining. Market power and its potential abuse against the poor and vulnerable are fundamental to how the bargaining dynamics play out. Ethics therefore lie at the very heart of economic analysis, the determination of prices and the distribution of wealth. The neoclassicals are right then that price is the enumeration of value at a particular time and place, but wrong to downplay the critical roles of bargaining, power and ethics in determining those same prices.

INTRODUCTION

Any attempt to model an economy requires foundational assumptions about the relations between prices, values and the distribution of wealth. These assumptions are often made at the beginning of the modelling exercise, with little thought to their import, yet they exert a profound influence over the results of any model. Unfortunately, there are few areas in economics as vexed as the theory of value. The titanic struggles between schools of thought descending from Smith, Ricardo, Marx, Keynes, Sraffa and modern neoclassicals, all revolved, to a greater or lesser extent, around the problems of the theory of value.

The economic literature is replete with analytic models from the different traditions which tweak one or two assumptions of the dominant model, and then show that these changes can significantly alter the model's predictions. If however, the goal is to produce an economy-wide model which, as far as humanly possible, corresponds to the real economy, a key objective must be to replace any grossly unrealistic assumptions which significantly affect the results, with ones that more closely reflect what we know of the economic system. Replacing all of the most 'unrealistic' foundational assumptions in an analytic model at once though, is impossible, because the model usually becomes completely intractable. I argue in this paper therefore that the fundamental problem with past theories of value is that it is simply not possible to model the determination of value, the formation of prices and the distribution of income in a real economy with analytic mathematical models. All such attempts leave out crucial processes or make unrealistic assumptions which significantly affect the models' results. These irreducible difficulties with traditional analytic mathematical economic modelling, suggest that agent-based simulation models offer the most promising way forward.

1. CONTROVERSIES IN THEORIES OF VALUE AND DISTRIBUTION

There have been two primary approaches to the theory of value, neither of which is entirely satisfactory. The first broadly labeled, *substance theories of value*, view value as a 'thing', a substance inherent in an object which is conserved in exchange (Mirowski, 1989a). Manifestations of the substance theory appear in various cost of production theories, where price reflects the cost of production, to the labour theory of value, codified by David Ricardo and used by Karl Marx as the lynch-pin of his system. For Marxists, the value of a commodity derives solely from the value of the labour power used to produce it - and therefore any profit is due to the exploitation of the workers, who were not given the full reward for their labour. The labour theory of value has been discredited because of its assumption that labour was the only 'factor' that contributed to the creation of value, and because of its fundamentally circular argument: How is the 'true' value of labour determined? By the value of production. And what is the 'true' value of production? The value of the labour 'embodied' in the product.

Neoclassical theorists took a completely different approach, arguing that price was identical with value (unlike substance theories where price could diverge from 'true' value). Price moreover was determined purely by the interaction of supply and demand. Value then, was completely *subjective*, existing only in the eye of the consumer. Returns to labour (wages) and capital (profits) were determined solely by their marginal contribution to production, so that each factor received its just reward by definition. So the identity $Y = wL + rK$, where Y = total value of production, L = total labour and K = total capital, assumed w, the wage rate = $\partial Y/\partial L$ and r, the profit rate = $\partial Y/\partial K$.

Problems with the neoclassical approach include assumptions concerning representative agents (Kirman, 1992), perfect competition, perfect and costless information and contract enforcement and complete markets for credit and risk (Greenwald & Stiglitz, 1986; Stiglitz 2002); aggregate production functions and infinite, smooth substitution between factors (Felipe & Fisher, 2003); distribution according to marginal products (Pasinetti, 2000); firms always on the production possibility frontier and firms' pricing decisions (Blinder *et al.* 1998; Lee, 1996); ignoring money and credit (Dillard, 1988); and perfectly rational agents with infinite computational capacity (Radner, 1968; Conlisk 1996). The list could go on (see Lee & Keen, 2004 for an overview), but here I will concentrate on just two areas.

First, one of the most important results to emerge from the detailed study of the Arrow-Debreu general equilibrium model, was the discovery by Sonnenschein (1972, 1973), Mantel (1974, 1976) and Debreu (1974), of some deeply worrying properties of aggregate excess demand functions – termed the SMD results after the authors. Kirman and Koch (1986), Kirman (1989), Mirowski (1989a), Rizvi (1994) and Saari (1995) discuss the SMD results in detail, showing that the foundational assumptions of the Walrasian general-equilibrium model imply arbitrary excess demand functions and therefore arbitrary equilibrium price sets.

Rizvi (1994, p. 363) summarizes the implications:

> "The impact of SMD theory is quite general … Its chief implication .. is that the hypothesis of individual rationality, and the other assumptions made at the micro-level, gives no guidance to an analysis of macro-level phenomena: the assumption of rationality or utility maximization is not enough to talk about social regularities. This is a significant conclusion and brings the microfoundations project in GET [General Equilibrium Theory] to an end. Of course, if one does not want to look for regularities at the macro level, the SMD results pose no problem; but every theorist who wants to argue that a change in some price variable … affects a corresponding quantity aggregate in a definite direction, cannot base this argument on GET."

Kirman (2004, p. 47) is similarly conclusive:

> "The full force of the Sonnenschein, Mantel, Debreu result is often not appreciated. They show that standard and restrictive assumptions on the preferences of individuals cannot guarantee stability. Yet without this, the intrinsic interest of economic analysis based on the General Equilibrium model is extremely limited."

Second, the very notion of equilibrium itself is misleading in theorising about real economies. This objection is not new and Mirowski (1989b) provides an excellent overview, concluding:

> "The mere fact that one may apply a fixed-point theorem to some very scantily specified convex sets has *no implications for economic description*." (p. 456, italics in original)

Young (1928) showed that generalised increasing returns to scale due to the size of the market, network effects and the increasing division of labour made any notion of 'equilibrium' suspect. Schumpeter (1934) based his theory of development on the disequilibrium created by innovation, entrepreneurship, and the creation of credit to finance new production. Kaldor (1975) summarized the core problem:

> "My basic objection to the theory of general equilibrium is not that it is abstract; … but that it starts from the wrong kind of abstraction and therefore … it gives a misleading impression of the nature and the manner of operation of economic forces." (p. 348)

In real economies, there is no equilibrium, only continuous change. Equilibrium is never reached because of constant changes in preferences and tastes; technological and organisational innovations; discoveries of new resources and new markets; inaccurate and evolving expectations of businesses, consumers, governments and speculators; changing demand for credit; the entry and exit of firms; the birth, learning, and death of citizens; changes in laws and government policies; imperfect information; generalized increasing returns to scale; random acts of impulse and irrationality; weather and climate events; changes in disease patterns, and so on. In commenting on Young (1928), Kaldor (1972) wrote:

> "the counter forces which are continually defeating the forces which make for economic equilibrium are more pervasive and more deeply rooted than we commonly realize. … The whole issue, as Young said [p. 535], is whether an "equilibrium of costs and advantages" is a meaningful notion in the presence of increasing returns. When every change in the use of resources – every reorganization of production activities – creates an opportunity for a further change *which would not have existed otherwise*, the notion of an 'optimum' allocation of resources … becomes a meaningless and contradictory notion: the pattern of the use of resources at any one time can be no more than a link in the chain of an unending sequence and the very distinction, vital to equilibrium economics, between resource-creation and resource allocation loses its validity." (p. 1245, italics in original).

The reader may be struck by the antiquity of some of the references cited. Clearly these problems have been recognized for decades. Why then does mainstream economics persist with this approach? I believe it is because analytic mathematical modelling itself precludes a more realistic approach to value theory, and until recently that technique was the only one available. The problem is *not* the use of mathematical modelling, but the *kind* of mathematical modelling used. Agent-based models, object-oriented programming and greatly increased computer power however, are opening up a new frontier.

2. AN AGENT-BASED DYNAMIC BARGAINING THEORY OF VALUE

Agent-based models (ABMs) are dynamic computer simulations of interacting heterogeneous agents which permit the integration of economic, political, environmental and social dynamics. ABMs are now used extensively in ecology, political science, anthropology, engineering, epidemiology and increasingly in finance and

economics (Tesfatsion, 2001). Agents may number in the tens of thousands or even millions. They interact through rules, which may themselves evolve. Agents may move on spatial network, grid or 'real' landscape based on Geographical Information Systems (GIS) data. Agents may have bounded rationality, adaptive learning algorithms and evolving preferences, and may range from representing an individual or household to a firm or government to a meta-agent collecting and analysing data and governing information feedback to the whole model

What would an agent-based approach to value theory look like? Here there is only space to outline the main characteristics of an ABM that could form the basis for modelling a dynamic bargaining theory of value and which could form the core of a more elaborate whole-economy model. A detailed description with simulation results is left for a future paper. We have seen that while the classical economists, including Marx, assumed a *substance* theory of value in which value was conserved in exchanges along the value chain, neoclassicals favoured a *subjective* approach, where supply and demand determined price (and therefore value), and marginal products determined factor returns. The ABM takes elements from both approaches, but in a quite different framework. Instead of mathematical formulas based on continuous differentiable functions, here we assume a large but finite number of heterogeneous commodities and agents with differing degrees of market power set in a spatial network.

The ABM contains many agents which represent individuals, who are born from specific parent agents, live finite lives and die (with a low random chance of early death). They have minimum subsistence requirements which must be met each period to prevent death. At birth, individuals are assigned a distribution of 'intelligence' based on a weighted average of that of their parents and a random component. Agents must attend 'school' as children to acquire the skills they need to find jobs as adults and their intelligence affects their ability to acquire skills. It is improved by schooling but may be permanently impaired by prolonged malnourishment. For reasons which will become clear, individuals are also randomly seeded with different propensities towards ethical conduct, which itself evolves as a result of positive or negative interactions with other agents.

The 'Government' agent is responsible for health, education and infrastructure services, the rule of law and economic management. It is funded through taxation. The legal and institutional framework must be included in an ABM to give agents realistic incentives. Particular attention must be paid to the modelling of property rights, contract enforcement, and some index of worker health and safety standards. A strong social safety net, which redistributes some of the wealth from the winners out of the process of 'creative destruction', is also essential. Without it, resistance to innovation is much greater, and rightly so, since those who are displaced by it would be destitute.

The economy is monetary and the Central Bank independently sets interest rates based on inflation targets. The banking system extends credit to entrepreneurs and firms, and some firms issue shares traded on the national stock-market. There is also an Information meta-agent which records recent transaction prices in different markets which buyers and sellers may access for a price, to represent search costs. There is not one Market, but a large number of markets separated spatially. Access to markets other than the one the agent is currently located in, depends on spatial distance, the availability and cost of transport between markets, the income of the agent and the agent's skill in accessing information about other markets. The 'law of one price' is unlikely to hold across dispersed markets. Sellers post prices based on their production costs and a desired markup. So in this sense, the value the seller places on the product, as enumerated in the posted price he desires, reflects a substance theory of value. The potential buyer however, has her own perception of the product's value based on her knowledge of the markets for that product, and the intrinsic value of the product to her at that time and place, which in turn is based on her personal needs and her budget constraint. The price of any actual transaction will emerge from a process of *bargaining*, with the result dependent on the respective market power and the degree of desperation for a sale of both buyer and seller. In a monopolistic market, the buyer has no market power and the monopolist can set prices. In a monopsonistic market, the seller has no power and the buyer can set prices. Between these two extremes lies a spectrum of market structures with 'perfect competition' approached only (if ever) in particular markets in the network at particular times, when there happens to be a very large number of both buyers and sellers wanting to trade at the same time.

Following Schumpeter (1934), profits arise from innovation in new products, new processes, new markets, new forms of organisation, or new sources of supply. These profits are eroded as other firms copy the innovation. Profits may also exist as a result of market fragmentation,

information asymmetries, search and transaction costs. The money supply expands endogenously via the extension of credit to business enterprises, and since real profits exist, this expansion is not completely reversed by the contraction in money supply that accompanies the repayment of loans.

In contrast to the Marxian view, profits are legitimate and do not simply depend on the extraction of the surplus value produced by workers. Other factors of production make a real contribution to the productive enterprise, including the entrepreneur who conceives the idea of the enterprise, the inventor who brings forth the new product or process, the managers whose organisational skill enables the operation to run smoothly, the machines and inputs used in production and the capitalist shareholder or banker, who provides the line of credit to begin operations and runs the risk of losing his money.

In contrast to the neoclassical view however, the returns to each factor of production do not simply depend on that factor's 'marginal product'. Returns are decided at each step in the value chain, and in each factor market, through the process of bargaining. At the extreme ends of the market power spectrum, bargaining may simply consist of one side saying 'take it or leave it'. In the labour market, workers apply for work at a firm's proffered wage rate. If they can afford to, they search for better jobs elsewhere or hold out for better offers. If unionized, workers may strike and receive a greater share of production revenues, but due to imperfect information and possible misperceptions about how much capitalists and managers are receiving, striking workers may also overplay their hand, fatally cripple the firm and discourage investment and innovation in that industry in that market. Bankrupted firms cease to exist and workers must find new employment.

Market power and its potential abuse against the poor and vulnerable are fundamental to how the bargaining dynamics play out. Ethical decisions on the use of this power therefore lie at the very heart of economic analysis, the determination of prices and the distribution of wealth. That is why agents are seeded with a distribution of ethical propensities. While Marx was wrong that exploitation is mathematically inseparable from the notion of profit, he was right that power asymmetries routinely result in workers being exploited. The neoclassical assumption that each factor of production simply receives its marginal product has for decades provided a pseudo-scientific veneer for what are in fact the results of bargaining processes that are heavily influenced by asymmetric power relations.

Ethical workers may agree to work hard and not to shirk, and ethical firms may reward their workers with a larger share of the profits and good working conditions. Unethical workers conversely, may shirk or steal company property, and unethical firms may take advantage of worker's vulnerability to drive down wages and working conditions, leading to a low-trust trap plagued by high worker turnover, low productivity, poor working conditions, and strikes. Since the ABM is a long-run dynamic model, a level of trust (or distrust) can be built up between buyers and sellers, or firms and workers, through repeated interactions. High levels of trust can improve efficiency, enabling firms to save some of the costs of monitoring workers and suppliers and reducing the number of strikes and the level of shirking.

In recognising the effects of ethics and the use of power in determining prices through a process of bargaining, we are no longer talking about an objective means of determining what a product is 'really' worth. The 'value' of a product or service is never an absolute; it is worth something *to someone* at a particular time and place. In other words, the value of a product is inherently relational. It does not have a meaningfully defined value apart from the degree to which the product is desired by other people. There is no 'true', unchanging value, known only to God. There are only the prices, determined in a given market, on a given day, where a seller agrees to sell to the highest bidder at a particular price. If a potential seller rejects all bids as too low, believing the product is worth more, she can refuse to sell (is she has that luxury) and wait for higher bids. But if she decides to sell to the highest bidder, then that is what the product was worth on that day, in that place. An observer may believe that both parties to the transaction were fools, not realising the object's 'true' value. He can then try to buy it from the new owner at a higher price, who would no doubt be grateful for the windfall profit. The second new owner may believe he can sell it for an even higher price in another market, and that it is 'worth' far more than he paid for it. But he will only know for sure if he actually finds interested buyers and starts taking bids.

Here I differ with Mirowski's (1990, p. 706) view that "value is about conservation principles and invariants." In a context of bargaining in spatially (and temporally) separated markets, there is no *a priori* reason why value should be conserved from one transaction to the next. The neoclassicals are right then, that price is the enumeration of value at a particular time and place, but wrong to downplay the critical roles of bargaining, power and ethics in determining those same prices.

3. CONCLUSIONS: BUT IS IT SCIENCE?

Since bargaining power and ethical judgements on how to use that power form the core of the dynamic agent-based theory of value outlined in this paper, there is a very real sense in which the theory is not 'scientific' (whatever that means). It denies that there exist mathematical formulae which will show what prices and factor returns 'should' be. In another sense however, the ABM approach outlined here is a far more 'scientific' approach to the modelling of a complex, adaptive physical and social system. It allows for human judgement, error, greed and compassion. As such, it offers an approach to modelling economies that may produce more realistic dynamics than conventional models. Two specific objections to ABMs may also be mentioned:

1. ABMs cannot 'prove' an economic theory.
The notion of what constitutes a legitimate 'proof' has been shaken in recent years by developments in mathematics. For centuries, a mathematical proof meant an analytic or geometric proof. Yet in 1976 the four-colour problem fell to another type of proof – computer calculations. The four-colour problem, dating from 1852, was the conjecture that a maximum of four colours was needed to colour a map of adjoining shapes without any two contiguous areas sharing the same colour. Kenneth Appel and Wolfgang Haken finally solved the problem in 1976 using both hand calculations, and 1200 hours of computer time. The use of computers in a mathematical proof was highly controversial and remained so into the 1990s until other teams reported the same result with different algorithms. "These days" concludes Devlin (1999, pp. 164-5), "almost all mathematicians acknowledge that the arrival of the computer has changed not only the way much mathematical research is carried out but also the very concept of what is regarded as proof. Checking the program that produces the 'proof' must now be allowed as a valid mathematical argument."

2. ABMs are ad hoc in their assumptions of parameter values
The point is sometimes lost that economics is not meant to be a branch of mathematical philosophy. An economic model, particularly if it is allowed anywhere near a policy question, should reflect as far as possible, the characteristics of the real economy it is intended to model. For that reason, while the particular values of the parameters of an ABM may certainly be open to question, we know for a fact that the rate and direction of people's change of preferences, for example, is not zero, as most analytic models would have it. Analytic models tend to deal with the problem of lack of data on key parameters by arbitrarily assigning them a value of zero. That approach has no more claim to scientific legitimacy than a careful 'guesstimate' of a sensible range of values – quite the opposite, since we often know for a fact that a parameter cannot be zero. This is not the place for a detailed discussion of the validation and testing of ABMs (see Kleijnen, 1998; Balci, 1998), however it is important to note that unlike many analytic models where the model is simply 'solved' for a unique solution, ABMs should be run thousands of times, varying key parameters over the plausible parameter space to obtain a distribution of outcomes with various probabilities.

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