(Un)Realistic Simulations of Financial Markets

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Abstract – *Communication on the state of (un)realistic microscopic simulations of financial markets.*

Keywords: Rational Expectations, Modern Portfolio Theory [Mar52, AD54, Sha64], Complexity and the Economy [Art99, Sol99], Continuous-time models survey [Mer90], Synchronous simulations survey [LLS00, PLLC99], SantaFe Artificial Stock Market [PAH$^+$94, LAP99, LeB02], Asynchronous simulations [MCFR00, **?**, Cap03, JLM04, BPBK04], Markets microstructure [DS99]

1 State of simulations

This workshop was rather unformal, with a special focus on the trading platform, but also with presentations by Professors around of their research group works and achievements. During those presentations – some of them by Economists considered non-mainstream and who had an interest in agent-based models – I realised how far away the agent-based research community is from being accepted by the Economists community. And that's not only a problem of different vocabulary. The role of Economics exists for the sake of policy making; originally, the Economists was the one who advised the Prince on what to do, which decisions to make, and what kind of consequences those decisions will have on the economic environment. And the origin of the success of General Equilibrium Theory is to be found in this major role of the Economist. This theory provides a perfect policy making tool: by changing this and that parameter, the Economy should move from this equilibrium to that one. This is a perfect justification for the Prince – nowadays politicians.

Now, the problem is that we don't really have a clue of what's going on, really, and measuring the real impact of Economic decisions such as raising interests rates, lowering taxes, etc. on the real Economy is almost impossible ... and cannot be falsified. In a nutshell, the General Equilibrium Theory is a perfect tool for politicians, a beautiful cathedral for Economists, but a rather fragile edifice for Scientists. And this is where the (Econo)Physicists entered the game. At the beginning of the 90's, Physicists specialised in Condensed Matter and Statistical Physics, facing decreasing funds sources due to the end of the cold war, saw a niche and seized the opportunity: they denounced the softeness of traditional Economics theories, and claimed that by applying their tools, if provided with enough research resources, they would be able to solve quickly problems that remained unsolved by generations of Economists. In particular, they would propose explanations for the inner dynamics of markets, leading to possibly exciting results on how markets could be modified to be more efficient (lower trading costs, prices reflecting all available information, reduced volatility). Quickly, money started flowing into the recently born community of EconoPhysicists.

10 years later, the Econophysicists still do not publish in the mainstrean Economics litterature. One of the reasons is their bad reputation in the field, which is understandable. But another, more worrying, is that they were unable to provide any concrete results that could foster interest in policy making, for instance. Taking the complex approach was expected to be hard, from the beginning, but it was extremely promising. Agent-based models replaced the narrow framework of homogeneity and rationality of representative agents by the more diverse and rich world of heterogeneous agents with bounded rationality, but at a high price: those models are not analitically tractable anymore, and simulations are required to see their evolution in time. With those new models came a new method(ology): the observation of stylised facts, the design of microscopic

properties and interactions between agents, and the run of batteries of simulation with the hope of reproducing those stylised facts. This bottom-up approach, seemingly very powerful thanks to its flexibility (almost every behaviour can be implemented), suffers a major flaw: the number of theories explaining stylised facts exceeds by far the number of facts themselves! (those facts are often reproduced qualitatively by models, but not quantitatively) Moreover, with the increase in flexibility came an explosion of dimensions in the parameters space, and one often needs a finu tuning of simulations to obtain credible results. Even if we suppose that the model behind is plausible, nothing is often said about the forces that would drive the parameters into the interesting region where stylised facts emerge, from instance.

Finally, when dealing with financial markets (securities exchanges, foreign exchanges, fixed-income) more precisely, another problem emerges: even if very complicated, those simulations are far from representing reality, from the practitioners (traders) viewpoint. Obviously, the point of a model is to be simpler than reality, but some details are striking. For instance, what is observed and recorded in markets (the price evolution tick by tick of the order book) does not represent the real supply and demand of stocks, and a big part of the volume exchanged everyday goes unnoticied via pairwise deals of big blocks of stocks between big institutions, pension funds, investment banks, etc. This is only an example.

Obviously, the Econophysicists will claim that as long as they do not understand completely the dynamics of simple markets, there is no interest in adding those details to their models. But what is the validity of their models to real markets, then? To what extent can their results remain valid in real markets? As you see, the search for the sufficient and necessary ingredients explaining the dynamics of financial markets is far from being achieved, and one might even wonder whether it will be at some point. But the only way to make any progress is definitely to involve Economists, Practitioners and Physicists on the same boat.

2 More about simulations

Even if the research communities in Economics and EconoPhysics are at loggerheads with each other, we can see some progress in the cooperation. A noticeable example is the participation of Markowitz in an asynchronous, discrete-time agent-based platform of financial markets. Here is the paper for future reference:

Financial Market Simulation http://www.jacobslevy.com/MktSim.htm

Direct link to the paper: http://www.jlem.com/articles/jlem/JLMsim.pdf

This paper was written by J. Jacobs and K. Levy, working for their own Equity Management firm. It is interesting to see that both practitioners and Economists are now using such approach. Also, this paper gives a nice introduction to the state of financial market simulations in: - continuous time – models analitically tractable based on differential equations; - synchronous discrete time – where the time increases by fixed increments, e.g. Moduleco at the moment; - asynchronous discrete time – also called event-driven approach, where the time progresses irregularly according to the succession of events.

Sorin Solomon (http://shum.huji.ac.il/ sorin/), my host in Torino where he is director of the Multi-Agent Systems Division of the Institute for Scientific Interchange (ISI, http://www.isi.it) Foundation, is a Physicist who developped an interest in microscopic representations of markets. Highlighting the limitations of continuous time models (he denounces the use of representative agents as being a highly unrealistic hypothesis), he proposed a few years ago a synchronous discrete time model called Levy-Levy-Solomon (LLS) model, which was quite successful in the community of Econophysicists. He wrote a book about it and received positive reviews by big names in the Economics community such as Markowitz

Microscopic Simulation of Financial Markets ; From Investor Behavior to Market Phenomena

For instance: "Levy, Levy, and Solomon's Microscopic Simulation of Financial Markets points us towards the future of financial economics. If we restrict ourselves to models which can be solved analytically, we will be modeling for our mutual entertainment, not to maximize explanatory or predictive power." –HARRY M. MARKOWITZ, President, Harry Markowitz Co., and Nobel Laureate in Economics.

Now he is moving forward, and describe such synchronous models as being relevant for coarse grain features of the market, and large time scales where the price can be defined as being an equilibrium between demand and supply, but rejects this framework for small lags (day trading) where the dynamics emerge not from the law of supply and demand, but from the asynchronous arrival of bids and asks in the order book.

In this framework, we don't need to assume that at each discrete instant t1, t2, etc. traders send their demand and supply curves to an omnipotent market maker who will define the equilibrium price, as in a Walrasian auction. Actually markets do not work that way, and instead limit orders flow into the order book and move the price when bid and ask meet, or a market order is sent. Those dynamics appear to be crucial to the price formation mechanism, and other Professors attending the workshop announced that they were moving towards this kind of more realistic market mechanism in their models.

Using this more realistic market mechanism opens new paths for research, while keeping a high flexibility in terms of agents behaviour. The ultimate aims of such models are to explain the link between market microstructures and macroscopic phenomena (for Physicists) but mainly to be used by Economists for policy making, once simulations are able to replicate realistic features. In particular, this approach could provide a brand new insight into the consequences on a market of the evolution of the population of traders (or investors) who participate in this market. From what I can see, we are still far from being able to replicate real markets, but this is a step in the right direction.

Now, from a behavioural point of view, the experiment we ran during this workshop can teach us a few things. First, we could witness the dynamics of people trying to define their strategy, and update them day after day according to their performance against others. Second, it was clear from the very first runs that some kind of regulation was needed, since some strategies could drive lead to explosions in the price, even with a small share of the market. We solved this problem partialy by introducing a large number of random traders, but this was not satisfactory. Traders involved in this simulation immediately recognised the need for a market maker, also called "specialist", who would provide liquidity and try to control volatility. Such specialists exist on the NYSE.

We observed that it was very difficult for traders to formulate a strategy that would reflect their own behaviour. Indeed, even if they were much more creative than others (e.g. coming up with strategies depending on the volume much more than the price), they felt rather constrained by the fact that they had to announce their strategy ex ante, and then see it evolving against others without possible intervention. They always told us that in this and that circumstance, they would have acted differently. In my opinion, part of this can be explained directly by the fact that traders are reluctant to admit the failure of their strategy a posteriori. They want to believe that they can beat the market with their own strategy, which cannot be formulated a priori.

Another explanation can probably be found in the traders feelings and the strategies that can be born on the spot, while playing live. We had this experience too. Another participant of the workshop, A. Cappellini, an Economist who works in an Italian investment bank and does a part time PhD with P. Terna, Univ. of Torin (http://web.econ.unito.it/terna/), had developped with others another kind of simulation, still asynchronous but in real time, with human traders interacting in an artificial market (with 3 stocks, a future and a riskless asset) against other humans and artificial traders. We played for two hours in front of our monitors – this application is actually very nice and one needs only a web browser to play; charts are provided for a limited tehnical analysis, and the order book is visible, like in real markets. Well, I can tell you that the behaviour of participants (including myself) was rather different from the quiet strategies we had coded on Sorin's platform. Indeed, many of our actions were influenced by the facts that we thought we could "feel" the market, and actually some surprising strategies emerged, such as entering some orders in the order book with law volume, but a low price for instance, to drive the price down artificially, counting on the fact that other participants see the book and will believe there is some useful information or significance in this order. We will discuss that.

3 What can be done

On one hand, existing models proposed by Economists and even Econophysicists appear very far from reality, with unrealistic assumptions and stylised market mechanisms which we know to be wrong (e.g. rationality and homogeneity of traders, Walrasian auction), or about which we don't know anything (e.g. the impact of trading on the price formation). On the other hand, existing simulations designed to be higly flexible and close to empirical markets, at the price of analytical tractability, are still judged by practitioners to be distances away from real markets.

3.1 Markets Microstructure

Real markets, whether they are equities exchanges (stocks), foreign exchanges (currencies) or fixed-income (money, bonds), follow a strict trading mechanism defining how orders are submitted and processed, and how prices are set. Those trading mechanisms vary across several dimensions:

- floor trading (open outcry) vs electronic trading (screen-based)
- single-price clearing (such as a batch auction) vs continuous auctions (limit order book)
- auction markets vs competitive dealer markets
- order-driven (quantities provided, not price) vs quote-driven (price provided, not quantities)
- open vs closed order book

3.2 Behavioural Finance

There are different directions we could push forward. From a Behavioural Economics viewpoint, we could use our artificial market as an experimental laboratory to study how people behave in a market environment, how they design their strategies (far from rational expectations), and how they update them through an iterative process driven by competition between agents, and leading to an acurate avatar representation of human behaviour. Behavioural Economists seem to have designed their own experiments, in their own labs, but what we offer is a highly rigorous and documented framework. An important litterature in Behavioural Economics exists that poses the question of best microstructure, or market mechanism, in terms of liquidity, transparency, transaction costs and market efficiency. Empirical studies also analyse the advantages of different existing market mechanisms, such as the call auction (or batch auction, often used to set the opening price), the contiunous auction (usually implemented as a limit order book) and the dealership market (usually prefered for markets with few participants but large orders, where anonymity if the key). This stream of research seems to be a natural way to go for the Agent-Based Computational Economics community. An important result so far is that the optimal trading structure depnds on the type of order flow the market receives, and the batch auction could be prefered to an open order book when actors do not want to reveal any information for instance.

From a more Econophysics-oriented point of view, this simulation platform, in between real markets and Econophysics models in terms of realism, is perfectly placed to test the hypotheses those models formulate, by placing them into the best market-like environment we know. The hedge we have is that this has never been done before, and every result will potentially be new and useful. By that, we mean that we could test simple models in highly realistic conditions.

In terms of expertise, this ambitious approach can be conducted by attracting not only physicists, but also psychologists to run experiments on people's behaviour, computer scientists to canonize this behaviour (or the ideal ones proposed by existing Econophysicists models) into artificial agents, practitioners to relate those experiments to real markets and provide us with useful knowledge about market mechanisms, and economists to eventually assess the consequences of our results in terms of policy making.

4 Limitations and risks of the agent-based approach

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