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Editors

Progress in Artificial Economics

Computational and Agent-Based Models

Springer

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Preface

This volume collects the contributions presented at the sixth event in the annual Artificial Economics conference. (For more information on former conferences, see http://www.artificial-economics.org/.) We received 48 submissions and based our acceptance decisions on a total of 137 referee's reports, leading to an average number of reports close to three per paper. We had to make difficult choices and we regret having been unable to include more papers.

Upon reaching a sixth anniversary, one should be able to answer a simple and basic question such as "What is Artificial Economics?" When working on this book, the editors came back to this question many times and had lively discussions leading to the conclusion that a proper answer requires a fair amount of care and ingenuity. Clearly, Artificial Economics lives in a neighborhood of Computational Economics. One of the editors likes to say that Computational Economics is an excellent first-order approximation to Artificial Economics. But what about the second order? Moreover, and more importantly, a commonly accepted definition of Computational Economics has still to come and, hence, this looks like a slippery avenue. Another editor suggests that the blend between Economics and Computer Science plays an important role in the definition of Artificial Economics scope and goals. Somehow, the *A* in Artificial rhymes well with the initials of algorithms and (economic) activities.

Artificial Economics is based on the consistent use of agent-based models and computational techniques. Virtually all contributions in this volume are interesting variations on one facet or another of these foundations. The richness and diversity underlying these models is now widely accepted as a useful companion for better understanding the experimental and theoretical results close to the heart of our scientific interests. Yet, we believe that this is not the whole story.

We would like to spell out the principle that what lies behind Artificial Economics are networks. (If you hear some background mumbling at this stage, this is a symptom of a healthy debate.) We can see at least three of these:

1. Artificial Economics connects disciplines like Economics, Management Science, and Computer Science... with a *fil rouge* emphasizing the role of agents, heterogeneity and evolution.
2. Artificial Economics links economic problems and approaches coming from different research areas, united by the need or opportunity to use simulations, numerical methods, and more generally heuristics in a broad sense;
3. Artificial Economics is made by a wide-casting network of scholars willing to recombine problems, ideas and solutions in innovative ways that draw inspiration from the areas mentioned above.

Ultimately, networks afford the multiplicity, diversity and resilience that are needed to explain our world and advance research. But the proof of the cake is in the pudding. Let us introduce the heterogenous papers appearing in this volume, conveniently (albeit somewhat arbitrarily) arranged in seven categories.

Markets and trading. Veryzhenko, Brandouy, and Mathieu tackle the question of how much sophistication is required from artificial traders to replicate well-known stylized facts in a realistic market microstructure. Hauser and Kaempff consider a market where agents are heterogeneously informed and introduce a new trading strategy that is shown to protect most of them from being exploited. Kodia, Ben Said, and Ghedira open a new front in the agent-based modeling of stylized facts for asset markets by explicitly considering behavior and cognitive attitudes.

Auctions. Brigui-Chtioui and Pinson propose a new bidding algorithm for the multicriteria English reverse auction protocol. Mochon, Saez, Gomez-Barroso, and Isasi present a simulator for the combinatorial first-price sealed-bid auction and test it over two environments inspired by current spectrum auctions. Posada and Hernández offer an agent-based perspective on recent experimental results about the performance of the continuous double auction in the presence of transaction costs.

Networks. Anand, Gai, and Marsili develop a simple model of how trust can break down in financial systems drawing on insights from the literature on coordination games and networks. Blasco and Pin study the adoption of a new technology as an instance of social learning, comparing the long-run efficiency of a network against the benchmark case of isolated agents. Taghawi-Nejad relies on a network of agents to illustrate how shocks due to the introduction of a new technology may lead to business cycles.

Management. Wall guides us into the analysis of how imperfect information affects performance under different organizational structures. Chie and Chen study different layers of the effects of social interactions on product innovation in a duopolistic dynamics. Lacagnina and Provenzano consider a multi-agent supply chain and exhibit situations of self-organized criticality that may create large fluctuations in the sector productions.

Industry Sectors. Mc Breen, Goffette-Nagot, and Jensen apply an agent-based model to provide a detailed study of the housing market that tracks the consequences of imperfect information. Schütte develops a model of product market competition and validates it using empirical data from the pharmaceutical industry in Germany. Osinga, Kramer, Hofstede, Roozmand, and Beulens investigate a complex market with many agents that is directly inspired by the Chinese pork sector.

Macroeconomics. Romanov, Yakovlev, and Lelchuk study the long-run distribution of wealth in a model with many classes of agents. Teglio, Raberto, and Cincotti report on the relationships between the availability of credit money and the variability of output and prices within the EURACE model. Hemmati, Nili, and Sadati analyze a linear-quadratic repeated inflation-unemployment game in an environment populated by heterogenous agents who use reinforcement learning to evaluate the governmental target.

Demography and culture. Giulioni and Bucciarelli apply an agent-based model to investigate the evolution of fertility and income in the process of economic development. Ruiz, Botti, Giret, Julian, Alvarado, Perez, and Rodriguez consider the effects of the labour market and of the financial sector on migration in a multi-agent simulation. Burgers, Hofstede, Jonker, and Verwaart offer a rich simulation of the impact of several cultural variables on trade.

As usual, the Conference was also enriched by two invited speakers whose (unofficial) job description is to alert us to new developments. Frank Westerhoff (University of Bamberg) gave us a wide introduction to his recent work on the use of models with heterogenous agents to probe the various effects of regulatory measures. Thomas Bäck (University of Leiden) shared with us his deep knowledge of the foundations and applications of evolutionary and bio-inspired algorithms that are becoming increasingly important for Artificial Economics and several other research areas.

To wrap things up, we would like to share that during the last hectic week when this volume was getting the final editing touches the editors were in France, Spain and Italy, respectively. Each of these three countries has played an important role in the development of the Artificial Economics series since its beginnings and, not coincidentally, this proves once again the importance of networking.

Venice,
May 2010

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Part I
Markets and Trading

Agent's Minimal Intelligence Calibration for Realistic Market Dynamics

Iryna Veryzhenko, Olivier Brandouy, and Philippe Mathieu

Abstract This paper investigates the question of how much sophisticated in behavior and intelligence artificial traders need to be in order to replicate both qualitative and quantitative stylized facts within a realistic market microstructure. For this purpose, we introduce an agent-based simulation environment with an architecture close to the Euronext-NYSE Stock Exchange. Series of experiments with different kinds of agents' behavior and trading framework specifications were realized within this environment. The results indicate that only special calibrations provide realistic stylized facts with coherent quantitative levels. We introduce a new type of agents, called in this paper "strongly calibrated agents", with their specific environment design, that provide price dynamics in quantitative and qualitative accordance with real stock market characteristics.

1 Introduction

Agent-Based Finance, and specifically, Agent-Based Artificial Stock Markets (hereafter ABASM) is an ever-growing field that appears, in the aftermath of the recent financial crisis, as a potential source for renewed analysis concerning the stability of the whole financial system. For example, policy experiments with agent based platforms become more realistic with the increasing sophistication of these softwares, and topics like the assessment of Tobin Tax regarding financial markets liquidity and volatility [9] or the analysis of the linkage market-microstructure and price dynamics [11] can actually be undertaken. One strong argument pleading for an increasing

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role of ABASM in the academics or policy-makers toolbox, is that these softwares can duplicate the main stylized facts that can be observed on real-world stock exchanges (see for a detailed review of stylized facts [5], and for a work involving ABASM in their emergence [6]). In this perspective, several research articles have argued that Zero Intelligence Traders (ZIT, “à la" [7]) are sufficient to produce such stylized facts (for instance [15]). Nevertheless, these stylized facts remain mainly *qualitatively* congruent with real-world observations and the underlying price motions emerging from ZIT interaction remain, to our opinion, rather unrealistic. If one wants to go beyond this mere qualitative approach, ABASM need some “calibration" to deliver price dynamics that *quantitatively* correspond to real financial markets motions on the one hand, and to produce more realistic price trajectories on the other hand. Such “calibration" must be done at the agents level and matched against real-world data. Furthermore, this process must also be grounded on a realistic market microstructure. Thus, the following question is at the bottom line of the present article : *"How basic artificial traders could be for realistic market simulations ?"*.

We show, using an asynchronous Agent-Based platform benchmarked against a major European stock market, that pure ZIT cannot reproduce realistic price dynamics especially when one focus on their quantitative values. We introduce an augmented intelligence specification that aim at delivering both qualitative and quantitative stylized facts and discuss previous results that supported this minimalist specification in Agent’s artificial intelligence.

The article is organized as follows. In a first section, we briefly review the relevant literature and point out the main results linking agents intelligence and financial price dynamics. We then describe the agent-based platform used for the experiments run in Sect.3, and the procedure that was used to verify the ability at mimicking its benchmark real stock market. In a fourth section, we describe our empirical strategy and present the main results we obtain.

2 Literature Review

2.1 Seminal Contribution and Initial Controversy

The minimal agents intelligence calibration became controversial when the much cited Gode and Sunder [7] model faced strong criticisms from Cliff and Bruten [4]. The main concern of this latter research was to evaluate how much intelligence is actually needed in agent to achieve high-level trading performance. Cliff and Bruten calibrated their system through agent’s ability to adjust their profits in order to achieve a “realistic market efficiency". Other kinds of calibrations have appeared afterwards. For example, some researchers tried to mix agents populations in their models to get stylized facts from behavior heterogeneity (see for example [1]). Later Maslov [10] improved an existing model using limit and market orders. This method has also been employed in the work of [12]. But their models reproduce only some of generic features: namely, a congruent Hurst exponent and fat tails in the return distribution. Challet and Stinchcombe [3] show that in continuous-double auction setting the model of three processes (orders, executions, cancellations) is required to produce the fat-tails and volatility clustering.

In this research we also focus attention on price dynamics itself : this point is usually ignored by authors although we believe it is an important validation instrument for market simulator success: amazingly, one can obtain stylized facts that match "at a qualitative level" real world dynamics with an underlying price series that is totally unrealistic at a first glance. Thus, for example, even if one can observe stylized facts from the return series delivered by the simulator, he can easily face a problem of (unrealistic) highly volatile price series. Therefore, computer simulations that provide realistic stable price dynamics are particularly interesting to our opinion. The Minimal Market Model (MMM) [2] is, with respect to the latter criterion, particularly promising. These authors claim that this simple model can reproduce real market features in both price and return terms. Voit [13] also programmed this model and tried to calibrate it. Simulations end up with very volatile price series. All simplifications failed at stabilizing this highly sensitive system.

One can notice that many research claim that stylized facts, like volatility clustering, positive correlation in order types or shape of the order book, are not directly driven by strategic behavior: the necessary and sufficient ingredients to generate these statistical properties could be a specific market microstructure and zero-intelligence agents. For instance, an exhaustive investigation has been done by [8, 11], who show that the choice of a protocol may have a substantial impact on the allocative effectiveness, and other criteria such as excess volume or price dispersion. Nevertheless, and to the best of our knowledge, no paper focuses on the calibration of ABASM such to obtain quantitative stylized facts and non-volatile price dynamic in line with real markets. Our target is to fill this gap and to propose simple parametric methods to calibrate agents behavior to provide realistic price and return dynamics in the ArTificial Open Market API (here-after ATOM, see `http://atom.univ-lille1.fr`). Moving from non-strategic behavior to simple intelligence elements we show that *any assumption about any kind of intelligence has an impact to stylized facts*. We first present the ATOM API, then introduce agents behavior specification within this environment.

3 ATOM and Real World Market

ATOM is a general environment for Agent-Based simulations of stock markets. It is based on an architecture close to the Euronext-NYSE Stock Exchange one. Agent-Based artificial stock markets aim at matching orders sent by virtual traders to fix quotation prices. Price formation is ruled by a negotiation system between sellers and buyers based on an asynchronous, double auction mechanism structured in an order book. Using this API, one can generate, play or replay order flows (whatever the origin of these order flows, real world or virtual agents population). One of the main advantages of ATOM consists in its modularity. This means that it can be viewed as a system where three main components interact: i) *Agents* and their behaviors, ii) *Markets* defined in terms of microstructure and iii) the *Artificial Economic World* (including an information engine and, potentially, several economic institutions such as banks, brokers, dealers...). The two first components can be used independently or together. Depending upon the researcher targets, the *Artificial Economic World* can be plugged or not in the simulations. For example, one can use the system for the evaluation of new regulation policies or market procedures, for assessing potential effects of taxes or new trading strategies in a sophisticated artificial financial environment. Thanks to its high modularity and its ability to mimic real-world environments, it can also serve as a research tool in Portfolio Management, Algorithmic Trading or Risk Management among others. From a pure technological point of view, ATOM can also be viewed as an order-flow replay engine. This means that bankers can test their algorithmic-trading strategies using historical data without modifying the existing price series or backtest the impact of their trading-agents in totally new price motions or market regimes generated by artificial traders. Several distinctive aspects of ATOM can be highlighted:

1. It can be used without any agent. One can directly send orders written in a text file (for example, a set of orders as it arrived on a given day, for a given real-world stock market) to each order-book implemented in the simulation. In this case, ATOM serves as a “replay-engine" and simulations merely rely on market microstructure. It therefore runs really fast (an entire day of trading in less than 5 seconds).
2. ATOM can use various kind of sophisticated agents with their own behaviors and intelligence. Thousands of these agents can evolve simultaneously, creating a truly heterogeneous population. Once designed, agents evolve by themselves, learning and adapting to their (financial) environment.
3. ATOM can mix human-beings and artificial traders in a single market using its network capabilities. This allows for a wide variety of configurations, from “experimental finance" classrooms with students, to competing strategies run independently. The scheduler can be set so to allow human agents to freeze the market during their decision process or not.
4. ATOM has been tested rigorously. It has the ability to replay perfectly an order flow actually sent to a given market with the same microstructure. The resulting price series (on the one hand, the “real-world" one and on the other hand, the ‘artificial" one) overlap perfectly. Moreover, given a population of agents, ATOM can generate stylized facts qualitatively similar to the market it is geared at mimicking.

Simulations in ATOM are organized as “round table discussions" and are based on an *equitably random* scheduler. Within every “round table discussion", agents are randomly interrogated using a uniformly distributed order. This latter feature ensures that each of them has an equal *possibility* of expressing its intentions. Notice