Market Microstructure: Can Dinosaurs Return? A Self-Organizing Map Approach under an Evolutionary Framework

Michael Kampouridis\(^1\), Shu-Heng Chen\(^2\), and Edward Tsang\(^1\)

\(^1\) School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, CO4 3SQ, UK
\(^2\) AI-Econ Center, Department of Economics, National Cheng Chi University, Taipei, Taiwan 11623

Abstract. This paper extends a previous market microstructure model, which investigated fraction dynamics of trading strategies. Our model consisted of two parts: Genetic Programming, which acted as an inference engine for trading rules, and Self-Organizing Maps (SOM), which was used for clustering the above rules into trading strategy types. However, for the purposes of the experiments of our previous work, we needed to make the assumption that SOM maps, and thus strategy types, remained the same over time. Nevertheless, this assumption could be considered as strict, and even unrealistic. In this paper, we relax this assumption. This offers a significant extension to our model, because it makes it more realistic. In addition, this extension allows us to investigate the dynamics of market behavior. We are interested in examining whether financial markets’ behavior is non-stationary, because this implies that strategies from the past cannot be applied to future time periods, unless they have co-evolved with the market. The results on an empirical financial market show that its behavior constantly changes; thus, agents’ strategies need to continuously adapt to the changes taking place in the market, in order to remain effective.

Keywords: Genetic Programming, Self-Organizing Maps, Market Microstructure, Market Behavior.

1 Introduction

There are several types of models in the agent-based financial markets literature. One way of categorizing them is to divide them into the \(N\)-type models and the Santa-Fe Institute (SFI) like ones. The former type of models focuses on the mesoscopic level of markets, by allowing agents to choose among different types of strategies. A typical example is the fundamentalist-chartist model. Agents in this model are presented with these two strategy types and at any given time they have to choose between these two. A typical area of investigation of these models is fraction dynamics, i.e., how the fractions of the different strategy types change over time. However, what is not presented in most of these models is
novelty-discovering agents. For instance, in the fundamentalist-chartists example, agents can only choose between these two types; they cannot create new strategies that do not fall into either of these types. On the other hand, the SFI-like models overcome this problem by focusing on the microscopic level of the markets. By using tools such as Genetic Programming \cite{7}, these models allow the creation and evolution of novel agents, which are not constrained by pre-specified strategy types. However, this kind of models tends to focus on price dynamics, rather than fraction dynamics \cite{2}.

In a previous work \cite{3}, we combined properties from the $N$-type and SFI-like models into a novel model. We first used Genetic Programming (GP) as a rule inference engine, which created and evolved autonomous agents; we then used Self-Organizing Maps (SOM) \cite{6} as a clustering machine, and thus re-created the mesoscopic level that the $N$-type models represent, where agents were categorized into different strategy types. We then investigated the short- and long-term dynamics of the fractions of strategies that existed in a financial market. Nevertheless, that study rested upon an important assumption, i.e., the maps derived from each time period were comparable with each other. This comparability assumption itself required that the types (clusters), as well as their operational specification, would not change over time. If this were not the case, the subsequent study would be questioned. This was mainly due to one technical step in our analysis called translation. The purpose of translation was to place the behavior of agents observed in one period into a different period and to recluster it for the further cross-period comparison. We could not meaningfully have done this without something like topological equivalence, which could not be sustained without the constancy of the types.

However, this assumption can be considered as strict and unrealistic. Strategy types do not necessarily remain the same over time. For instance, if a chartist strategy type exists in time $t$, it is not certain it will also exist in $t + 1$. If market conditions change dramatically, the agents might consider other strategy types as more effective and choose them. The chartist strategy would then stop existing.

In this paper, we relax the above assumption, since our current work does not require cross-period comparisons. Our model thus becomes more realistic. In addition, we shift our focus from fraction dynamics to behavior dynamics: we examine the plausibility of an observation made under artificial markets \cite{1}, which suggests that the nature of financial markets constantly changes. This implies that trading strategies need to constantly co-evolve with the markets; if they do not, they become obsolete or dinosaurs \cite{1}. We hence test if this observation holds in the ‘real’ world, under an empirical financial market. This will offer important insights regarding the behavior dynamics of the markets.

The rest of this paper is organized as follows: Section 2 presents our model, and Sect. 3 briefly presents the GP algorithm we use. Section 4 then presents the experimental designs, Sect. 5 reviews the testing methodology, and Sect. 6 presents the results of our experiments. Finally, Sect. 7 concludes this paper.

\begin{footnote}{1 We refer the reader to \cite{2}, which provides a thorough review on both $N$-type and SFI-like models, along with a detailed list of them.}