Agent-Based Analysis of Asset Pricing under Ambiguous Information

(Extended Abstract)

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ABSTRACT

In a representative agent model, the behavior of a social system is described in terms of a single aggregate decision maker. Such models are popular in economic and finance research, largely due to their analytic tractability, but fail to account for real-world agent heterogeneity. Agent-based models naturally incorporate heterogeneity, but are seen as hard to generalize. We propose an empirical game-theoretic approach to address this concern, and provide a case study to demonstrate this approach.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems*

General Terms

Economics

Keywords

agent-based finance, empirical game theory, equity premium

1. INTRODUCTION

High-fidelity simulation has become an increasingly attractive option for investigating implications of alternative agent behaviors. In simulation we can conduct controlled experiments, and modulate environmental assumptions in a fine-grained manner. Despite the benefits of the *agent-based modeling* (ABM) approach, its adoption has been slow in the mainstream economic and finance research communities.

Leombruni and Richiardi [3] attribute this to the prevalent belief that agent-based models are "difficult to interpret and generalize". The difficulty of generalization stems in part from the potential sensitivity of results to the particular configurations of agent types and strategies chosen by the modeler. ABM designs allow more degrees of freedom than a representative agent model, and none produce the the crisp results of an analytical model.

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We propose an ABM methodology that addresses the concern of generalization. First, rather than impose a profile of agent strategies, we employ game-theoretic analysis. For a market domain, we simulate the market of interest to construct a game model. Equilibria of this game are taken as the expected market composition with respect to the pool of candidate strategies. We can then estimate outcome variables of interest with respect to the expected market composition through repeated simulation and the application of variance reduction techniques. Using this methodology, we investigate a recent model of ambiguity aversion in financial traders and its ability to resolve a famous problem in finance research: the equity premium puzzle.

2. BACKGROUND

Despite a burgeoning literature on ABM, it remains almost *de rigeur* in mainstream finance research to model aggregate behavior in financial markets analytically with a single representative agent. Such agents represent, in aggregate form, the preferences of all the agents in the market, and are assumed to hold all assets in a market in equilibrium. From these abstractions, pricing and other behavior is derived. Chapman and Polkovnichenko [1] have recently shown that the lack of agent heterogeneity inherent in the representative agent approach may have important implications, particularly when the agent is not an expected utility maximizer. Specifically, these authors demonstrated that adding even one more agent to a market can qualitatively change the conclusions of an asset pricing study. Adding agents to an analytical model, however, increases the complexity, and beyond a point the model becomes computationally infeasible.

3. AMBIGUITY AVERSION AND THE EQUITY PREMIUM PUZZLE

In standard models of asset pricing, investors demand a higher rate of return as the risk of an asset increases. This is a direct consequence of risk-averse utility: given a choice among two assets with the same expected value, the one with lower risk provides greater expected utility. The *equity premium puzzle* refers to the apparent disparity between the average return on equity securities (stocks) compared to bonds, and the predicted return based on their historical risk and reasonable risk attitudes of investors. Epstein and Schneider [2] (ES) argue that aversion to ambiguity can justify why even a market of well-diversified investors may still demand compensation for the idiosyncratic risk associated

with each asset they hold. ES model ambiguity aversion by worst-case reasoning over multiple priors on the future dividend payments of a risky asset, along with a premium for enduring ambiguous information. Since ambiguity cannot be diversified away, this could explain equity premia.

4. EMPIRICAL GAME MODEL OF ASSET PRICING

Taking the ES model as a starting point, we seek to address two questions. First, given the possibility of multiple strategies, is the ambiguity-averse strategy actually present in equilibrium? Second, in a model with agent heterogeneity and an active market mechanism, does pricing according to the ES model generate significant equity premium? To answer these questions, we constructed an ABM for asset pricing, and performed empirical game-theoretic analysis to evaluate strategy candidates.

As with ES, we model agents pricing a risky asset (stock) with reference to a risk-free asset (cash). We propose a continuous double auction (CDA) as the mechanism for agent interaction, and use market transactions as our basis for price. The equilibrium bidding strategy in this context is unknown, thus we must evaluate a space of candidates to determine an appropriate composition of agent strategies in the model. We adopt a version of the approach called *empirical game-theoretic analysis* (EGTA) [4]. The EGTA framework performs agent-based simulation to generate sample payoffs for candidate strategy profiles, and from them induces a game form. The learned game model then serves as the basis for game-theoretic analysis, which identifies stable strategy profiles (e.g., Nash equilibria).

Once we have identified stable strategy profiles we perform another round of simulation, with strategies distributed among agents according to their probability of play in the stable profile. In this round of simulation, we calculate equity premium by comparing the return on investments between the risky asset and the risk free asset.

5. EXPERIMENTS

We calculated equity premia estimates for 27 market configurations with 12 possible strategies, all parameterized versions of either the ambiguity-averse or expected utility maximizing strategy. Agents in these simulations feature constant relative risk aversion. Selected equity premia estimates are presented in Figure 1. The vertical axis measures the excess return on the risky asset versus the risk-free asset, estimated by simulating the market with a given parameter setting. We find that ambiguity aversion without risk aversion generates negligible premia, while ambiguity aversion with risk aversion often overestimates equity premium, relative to the expected equity premium in equilibrium. Thus, the ES model of ambiguity aversion does little to resolve the equity premium puzzle in these simulations.

We also found that the estimates of equity premium were sensitive to the number of learning and trading periods per quarter. These numbers place bounds on the liquidity in the market, as well as agents' ability to generate accurate prices. These results are presented in Figure 2. Increasing the number of learning episodes and trading periods per quarter dramatically reduces the observed equity premium in our simulations.

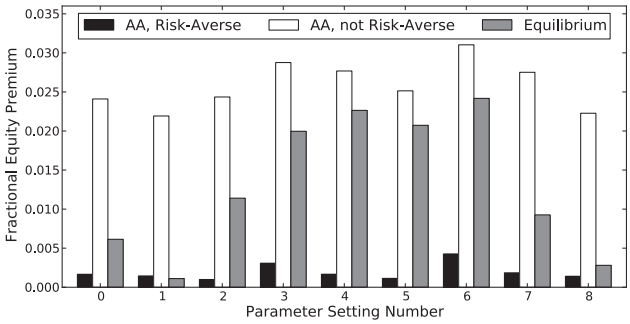

Figure 1: Calculated Equity Premium.

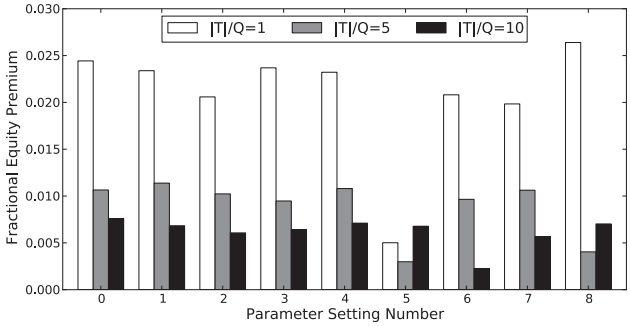

Figure 2: Equity Premium, Varying Quarter Lengths.

6. DISCUSSION

When market variables are derived through agent interaction, the estimation of these variables can be very complex. Analytical pricing models abstract away much of the complexity, but these abstractions may dramatically color predictions. Our agent-based modeling approach enables a higher-fidelity description of the agents and environment, while leveraging well established economic techniques. Applying this approach to the question of equity premium, we found that estimates of equity premium were sensitive to market composition as well market structure. These components are not specified by most analytical models, making generalization from such models questionable. Thus, agent-based modeling should complement analytical models in investigating parameter sensitivity, and guide us toward selecting more robust models of macroeconomic phenomena.

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