Security Design in Markets with Risk: Price and Allocation Efficiencies

1 General Background

General equilibrium has become the widely accepted theoretical model for competitive markets and the benchmark against which those markets are empirically evaluated. It is the basis of asset pricing theory and postulates that as long as markets are complete, i.e., as long as the uncertainty space is spanned by the existing assets, economic agents will arrive at consumption bundles that are identical across security design scenarios. Importantly, the consumption plans are Pareto optimal– no change in the rules of engagement can make any agent better off without reducing the welfare of another.

A compelling reason to be interested in equilibrium in this simple environment with symmetric information is the argument, familiar from Marshall, that there are forces at work in any actual economy that tend to drive an economy toward an equilibrium if it is not in equilibrium already, see Arrow and Hahn (1971). While there is wide consensus as to the appropriate equilibrium model, there is little consensus as to the "forces at work." Many models have been proposed, but none have been accepted as the appropriate canonical model.

Until recently, attempts to settle this question have been theoretical in nature. Traditional empirical analyses of markets shed little light on the processes because they do not have access to the fundamentals. But, with the advent and development of a methodology of experimental economics, it is now possible to shed light on the forces that drive markets to equilibrium. One can create markets in the lab (among others, see Smith (1962); Bossaerts and Plott (2004); Asparouhova, Bossaerts, and Plott (2003)). In those markets, it is possible to not only to know the fundamentals, but also to control them, and so, to observe the process of price discovery in a replicable and controlled manner.

In a recent paper, Asparouhova, Bossaerts, and Ledyard (2019a), referred to as ABL from here on, propose a Marshallian model for price and quantity adjustment in parallel continuous double auctions. In this theory, investors submit orders only for small quantities (an assumption that can not only be theoretically justified but can be empirically demonstrated), and at prices that maximize local utility. Optimality of allocations, on which equilibrium asset pricing theory is built, is eventually reached but markets take time before they arrive there. Experiments show that, consistent with the theory (i) price changes cross-autocorrelate with excess demands depending on covariances of liquidating dividends, contrary to the standard Walrasian price adjustment model and (ii) individual portfolios are under-diversified, and more so when dividend covariances are positive. The latter result echoes that of Bossaerts, Plott, and Zame (2007) in that while prices converge to their equilibrium levels, allocations do not. ABL provides strong evidence that the allocation convergence is weaker when the traded securities are positively correlated and provides theoretical foundations for why this is the case.

Since markets do not equlibrate instantaneously, those with security structures that are negatively correlated will converge faster to equilibrium. This project is set to address the question of the link between market efficiency (both price and allocation efficiency) and securities design.

The main hypothesis is that securities that are negatively correlated would provide the fastest convergence towards equilibrium allocations. This prediction is at odds with the observed prevalence of index funds that tend to be positively correlated. Unfortunately, lacking individual portfolio information, the question of whether index funds provide better outcomes than an alternatively structured financial system cannot be answered based on historical data.

2 Theoretical and Empirical Significance

Absent an accurate model, applied economists have generally assumed that markets are always in equilibrium, and that absent asymmetric information, security design is only relevant in its uncertainty spanning properties, and have hoped that the dynamics were fast and stable enough to justify those assumptions. But behavior is what it is, not what one assumes. If an inappropriate model is used in the design of economic policy, outcomes will not be as intended.

The issue of security design has become ever more pressing, because of two developments. First, in investments, price-insensitive strategies have become popular, often prompted by equilibrium theoretical reasoning, such as buying-and-holding an index, momentum investing, etc. (Lo and Wang (2000)) If agents hold initial portfolios with idiosyncratic risk (such as housing, non-tradable human capital, etc.), index funds, for example, are unlikely to lead the economy to its Pareto optimal allocations. Second, robots (algorithmic traders) have slowly taken over most of trading in financial markets. The research agenda following this project will address the algorithmic trading question. Security design becomes crucial if some humans rely on algorithms to maintain their portfolio as the trading strategies and their implementations would be vastly different under different security systems. As such the equilibration properties and the resulting welfare properties will also be different (and possibly Pareto ranked) under the different systems.

3 Goals, Objectives and Anticipated Results

The goal of the proposed research is to investigate the question: How does the security structure in place affect (i) the equilibration path of a market with multiple risky securities and (ii) the price and allocation efficiency on the equilibration path? The objectives of this project are tri-fold:

Objective 1. Build an experimental framework with multiple interdependent markets that would be used to test the implications a theory that focuses on off-equilibrium dynamics.

Objective 2. Apply a newly developed equilibration theory that focuses on off-equilibrium dynamics to the issue of securities design. In standard General Equilibrium theory if markets are complete, welfare properties are invariant to security design. This is not the case off-equilibrium and optimal security design may exist.

Objective 3. Translate experimental hypotheses into hypotheses about historical data.

The project will consists of two parts:

I. Simulation Analysis and Experimental Design

II. Conducting of Experiments and Empirical Evaluation

4 Methods and Resources

4.1 Part I: Theoretical Framework and Simulations

Part I of the project will employ past research expertise of the PI of the project as well as the co-PI, a former student, Wenhao Yang. The simulation analysis and the statistical methods will follow ABL's methods as well as the simulation methods used in Asparouhova, Bossaerts, and Yang (2019b). Based on the simulation analysis, the experimental design that provides the highest discriminatory power between security systems will be selected. In addition to Wenhao Yang, two undergraduate student will be involved in the simulation analysis, one from Business and one from CS/Engineering. The simulations will be conducted in BUC 202, and if needed will also utilize the Center for High Performance Computing at the University of Utah.

There are I consumers, and $K = 1 + R$ commodities, with the first indexed by 0 and designated as numeraire. Each i owns initial endowments $\omega^i = (\omega^i_0, \dots, \omega^i_K)$ s.t. $\omega^i_k > 0$ for all i and k. $x^i_t = \left(s^i_t, r^i_{1,t} \dots, r^i_{R,t}\right)$ is the allocation of consumer i at time t. Let $d^i_t \in \Re^K$ be a vector of cumulative net trades up until time t. $x^i_t = \omega^i + d^i_t$. Finally, each i has a quasi-concave utility function, $u^i(x)$. Denote prices $p_t = (1, q_t)$ and let $\rho^i_{k,t}$ be i's marginal rate of substitution between commodities 0 and k. $\rho^i_t = (\rho^i_{1,t}, ..., \rho^i_{R,t})$. Let the change in i's holdings at time t be Δx^i_t and b^i_t be i's bid or stated marginal willingness to pay.

4.1.1 The Model.

$$r^i_{k,t+\Delta t} = r^i_{k,t} + \alpha_k(q_{k,t-\Delta t} - q_{k,t}) + c^i \Delta t(\rho^i_{k,t} - q_{k,t-\Delta t}) \tag{1}$$

$$s^i_{t+\Delta t} = s_t - q_t \cdot (r^i_t - r^i_{t-\Delta t}) \tag{2}$$

$$q_{k,t} = q_{k,t-\Delta t} + \frac{\bar{c}\Delta t}{\alpha_k}(\bar{\rho}_{k,t} - q_{k,t-\Delta t}) \tag{3}$$

$$q_0 = \bar{\rho}_0 \tag{4}$$

During the adjustment, it is possible that $du^i/dt < 0$. With the bidding lag, it follows that $du^i_t/dt = u^i_{0,t}\{(\rho^i_t - q_t)c^i(\rho^i_t - q_t) - \sum_k(\rho^i_{k,t} - q_{k,t})\alpha_k(dq_k/dt)\}$ While the first term is positive if $\rho^i_t \neq q_t$, the second is not necessarily so. Traders basing their bids on lagged prices do not anticipate and protect themselves from "ex post" adverse trades.

4.2 Part II: Experiments

Part II of the project will once again employ experimental methods and standard (but sophisticated) econometric techniques as in Bossaerts et al. (2007); Asparouhova et al. (2019a,b). The experiments will be conducted at the U of Utah and U of Cincinnati. This proposal asks only for the U of Utah portion of the experimental subjects funding (100 subjects). The experiments will be conducted in SFEBB 5140, a designated laboratory space for behavioral experiments. The undergraduate students will help with conducting the experimental sessions and the formatting of the raw data, as well as performing basic statistical analysis on it. The higher level statistical analysis will be performed by the three co-PIs but will be also taught to the research assistants.

Each session consists of a number of independent replications called *periods*. At the start of a period, participants are given an initial position (endowment) in three securities, A, B, and *Notes*, and some cash. The markets for the securities are simultaneously open for a pre-set amount of time. The trading interface is a fully electronic web-based version of a CDA, see flexemarkets.com. After markets close, at the end of a period, participants receive payoffs according to the given payoff function.

Each session needs 20 participants. The scale is chosen to ensure a trading environment that best approximates the conditions of the theory: markets are large enough so that bid-ask spreads are small; markets are small enough so that only small quantities can be traded at the best ask and best bid.